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NORTHERN BOBWHITE (Colinus virginianus)

Section 4.1.3, US ARMY CORPS OF ENGINEERS WILDLIFE RESOURCES MANAGEMENT MANUAL

by

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13. ABSTRACT *(Maximum 200 words)*

The northern bobwhite (*Colinus virginianus*) is an upland game bird that occurs in agricultural lands, forests, and rangelands throughout the central and eastern United States. The bobwhite is an extremely popular small game species and is harvested in greater numbers than any other nonmigratory upland game bird in North America. Federal, State, and private conservation and management programs often feature the bobwhite in suitable habitat throughout its range.

A report on the bobwhite is provided as Section 4.1.3 of the US Army Corps of Engineers Wildlife Resources Management Manual. The purpose of the report is to provide Department of Defense and Corps of Engineers biologists with the information needed to effectively manage installations or project lands for this species. Major topics covered in the report include distribution, status, species characteristics, population attributes, habitat requirements, and management.

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The geographic range of the northern bobwhite is described, and its status as a game species is discussed. Diagnostic characters are presented, and methods for distinguishing sex and age are provided. Population information includes sections on the covey, population density, sex and age ratios, home range, breeding biology, productivity, and mortality.

The emphasis of the report is on habitat requirements and population management. The bobwhite's food and cover requirements are discussed, and details are provided on protective cover, roosting cover, nesting cover, and brood-rearing habitat. The management section includes topical information on population surveys, objectives, habitat management, and managing the harvest. Guidelines and recommendations are provided for managing bobwhite populations throughout the species' range. Management goals and strategies are discussed from a regional perspective, and alternative methods to improve habitat quality are presented.

PREFACE

This work was sponsored by the US Army Corps of Engineers (USACE) Environmental Impact Research Program (EIRP) and the Department of Defense (DOD) military branches under the Defense Natural Resources Program. Technical Monitors for the study were Dr. John Bushman, Mr. David P. Buelow, and Mr. Dave Mathis of the Headquarters, USACE, and representatives of the Fish and Wildlife Committee of the Defense Natural Resources Group, DOD. The report serves as a section of the US Army Corps of Engineers Wildlife Resources Management Manual, as developed by the Headquarters, USACE, under EIRP Work Unit 32420.

This report was prepared by Dr. Ralph W. Dimmick, Wildlife Consultant, Environmental Enterprise, Knoxville, Tennessee, under Contract No. DACA39-88-M-0653 with the Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES). Mr. Chester O. Martin, Team Leader, Wildlife Resources Team, Resource Analysis Group (RAG), EL, was principal investigator for the work unit. WES review was provided by Mr. Martin, Dr. Thomas H. Roberts, Dr. Wilma A. Mitchell, Mr. Kevin L. Grosz, and Dr. William P. Kuvlesky, EL. Dr. Roberts is now with the Department of Biology, Tennessee Technological University, Cookeville, Tennessee. Mr. Grosz, formerly with North Dakota State University under contract to WES, is presently a biologist for The Resource Company, Vancouver, Washington. Dr. Kuvlesky is under contract to WES from the Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, Texas.

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This report was prepared under the general supervision of Mr. H. Roger Hamilton, Chief, RAG; Dr. Conrad J. Kirby, Chief, Environmental Resources Division; and Dr. John Harrison, Chief, EL. Dr. Roger T. Saucier, WES, was Program Manager, EIRP. The report was edited by Ms. Jessica S. Ruff of the WES Information Technology Laboratory (ITL). Drawings were prepared by Mr. Charles C. Calais and Mr. John R. Harris, ITL.

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NOTE TO READER

This report is designated as Section 4.1.3 in Chapter 4 -- WILDLIFE SPECIES ACCOUNTS, Part 4.1 -- GAME BIRDS, of the US ARMY CORPS OF ENGINEERS WILDLIFE RESOURCES MANAGEMENT MANUAL. Each section of the manual is published as a separate Technical Report but is designed for use as a unit of the manual. For best retrieval, this report should be filed according to section number within Chapter 4.

NORTHERN BOBWHITE (*Colinus virginianus*)

Section 4.1.3, US ARMY CORPS OF ENGINEERS
WILDLIFE RESOURCES MANAGEMENT MANUAL

The northern bobwhite (*Colinus virginianus*) (Fig. 1) is an upland game bird that occurs in agricultural lands, forests, and rangelands throughout the central and eastern United States. Distinctive characteristics are its relatively small size (about 6 to 8 oz), its habit of living in small groups called coveys, and its clear, distinctive "bob-white" whistle heard from early March through midsummer. Its short, stubby beak enables it to eat a wide variety of foods, principally seeds and insects found on the ground. The feet and legs are structured for walking and scratching the ground surface. Short, rounded wings and powerful breast muscles enable the bird to flush explosively and fly short distances into and through dense vegetative cover.

Bobwhites are arranged taxonomically in the subfamily Odontophorinae (quails) of the family Phasianidae, which also includes the partridges and pheasants. The species is the sole member of the genus *Colinus*, but is related to 5 other species of quail in North America north of Mexico.

Figure 1. The northern bobwhite: male (left) and female (right) in typical plumage

Throughout its range the northern bobwhite is called quail, bobwhite, or bobwhite quail, and in the southeastern portion of its range it is often referred to as partridge. When Southerners go "bird hunting," they are invariably hunting bobwhites.

DISTRIBUTION

The bobwhite occurs principally in the eastern half of the United States, eastern Mexico, and portions of Central America (Fig. 2). It also occurs throughout Cuba and in extreme southeastern Ontario but is absent from most of New England. In the United States, its western boundary is characterized by finger-like extensions of forests along major river systems into the otherwise treeless grasslands. To the north, bobwhites reach the interface between the eastern deciduous and boreal forests. Disjunct, scattered populations persist in Washington, Oregon, and Idaho, resulting from introductions of various races of bobwhites from the Midwest and East.

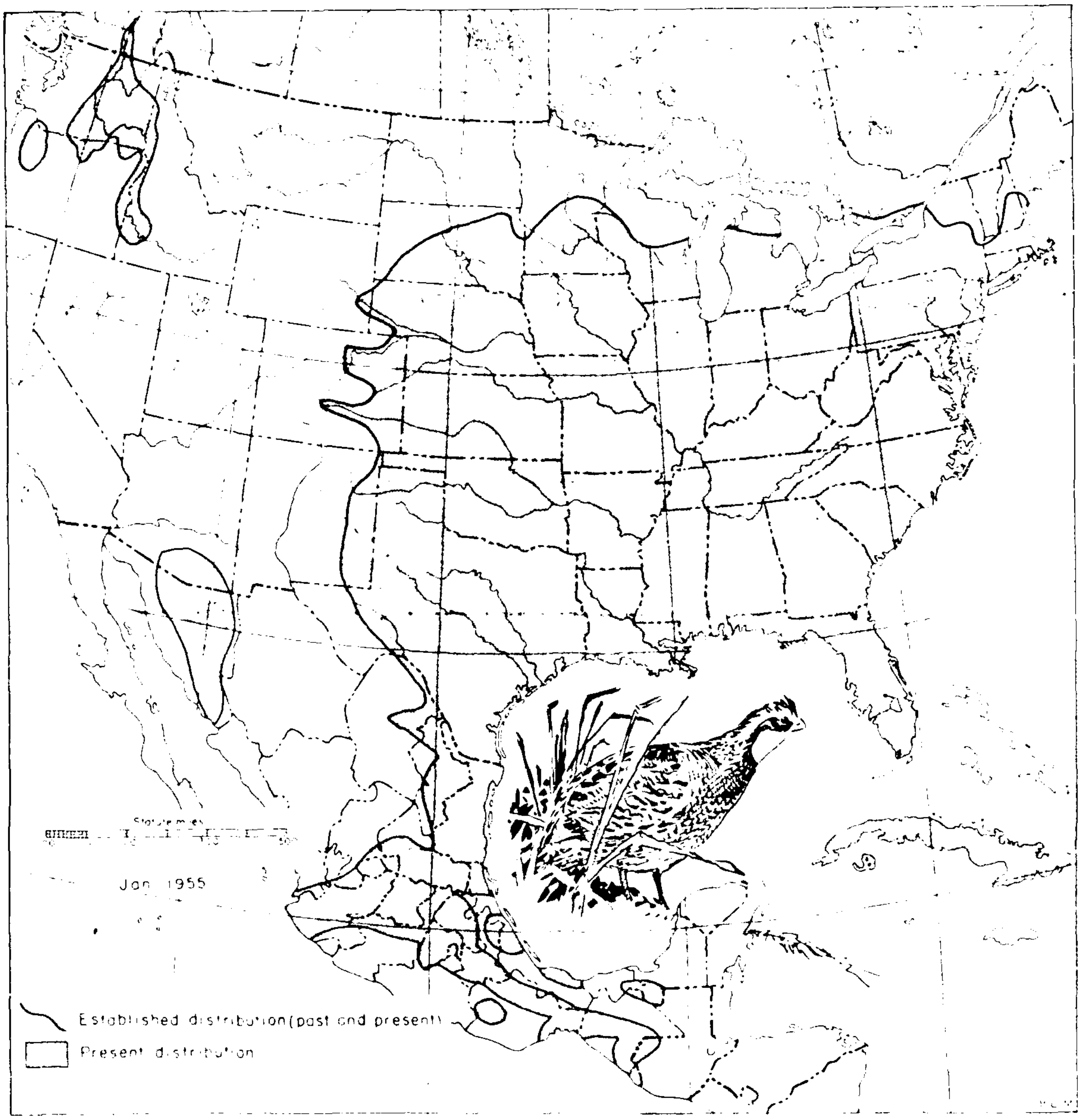

Figure 2. Geographic range of the northern bobwhite in North America showing past and present distribution (Aldrich and Duvall 1955); disjunct populations in the Northwest are the result of introductions of birds from the midwestern and eastern states

Twenty-two subspecies of bobwhites are recognized (Johnsgard 1973), 7 of which occur north of Mexico. Six of the United States subspecies compose a contiguous population ranging from the eastern Great Plains to the Atlantic Coast (Fig. 3). The subspecific status of some local populations may be questionable due to historical trap and release programs, which have resulted in mixing of birds from different populations throughout the species' range.

Over most of its United States range, the northern bobwhite is the only species of quail present. In western Oklahoma and Texas, bobwhites share the range with scaled quail (*Callipepla squamata*). Masked bobwhite are sympatric with Gambel's quail (*Callipepla gambelii*), scaled quail, and Montezuma quail (*Cyrtonyx montezumae*) in Arizona. Bobwhites may also occur in the same general range of the California quail (*Callipepla californica*) and mountain quail (*Oreortyx pictus*) in the Pacific Northwest.

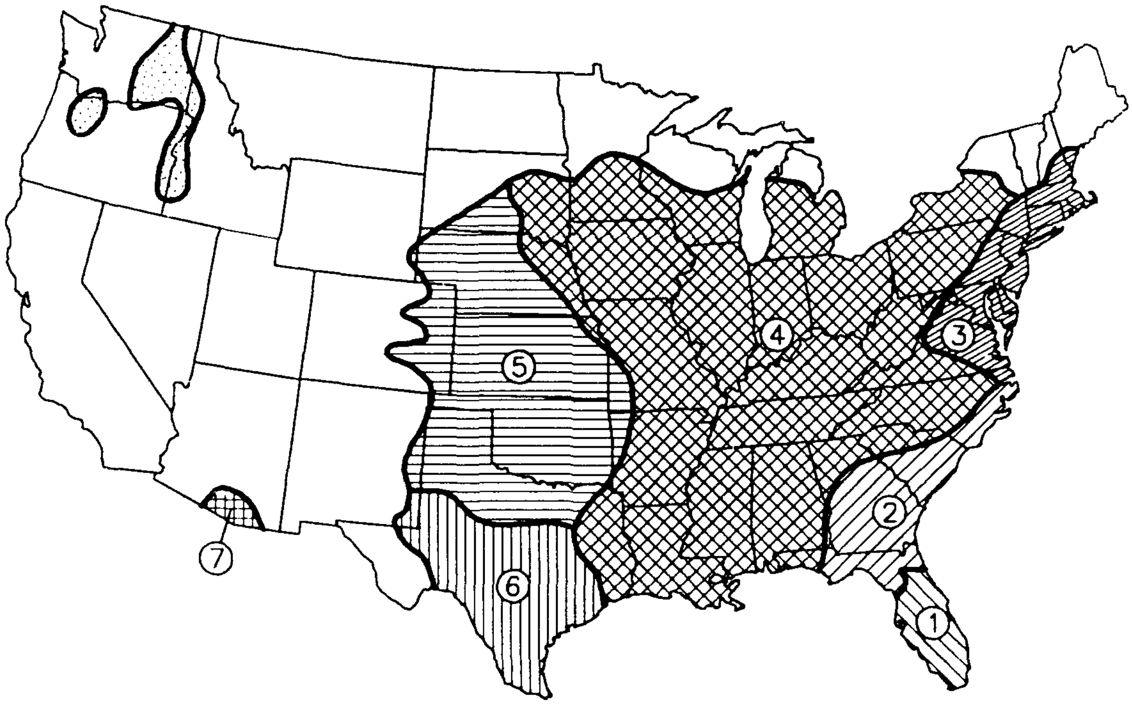

Figure 3. Distribution of United States subspecies of the northern bobwhite: (1) Florida race (*C. v. floridanus*); (2) Eastern race (*C. v. virginianus*); (3) New England race (*C. v. marilandicus*;) (4) Interior race (*C. v. mexicanus*;) (5) Plains race (*C. v. taylori*;) (6) Texas race (*C. v. texanus*); and (7) Masked race (*C. v. ridgwayi*). Northwestern populations do not represent a distinct subspecies (after Aldrich and Duvall 1955)

STATUS

Bobwhites are harvested in greater numbers than any other nonmigratory upland game bird in North America. Annual harvest in 1970 was estimated to total 35 million birds in 37 states and 2 Canadian provinces (Johnsgard 1973). Thirteen states harvest more than 1 million bobwhites annually (Johnsgard 1973). Texas (8 million) and Oklahoma (3 million) lead all states. In the Southeast, Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia each harvest 1 million to 2.5 million quail annually. In the southern Midwest, Missouri (2.8 million) and Illinois (2.0 million) lead the region by wide margins. Harvests have likely trended downward during the past 2 decades due to decreased habitat, but the bobwhite is still the most commonly taken nonmigratory bird species.

In 1988, 36 states specifically listed regulations for hunting bobwhites or included them in a combined bag limit for all quail (Appendix A). Connecticut, Oregon, and New Mexico are the only states with bobwhite populations that currently list no regulations for their harvest. In Minnesota the bobwhite is designated a protected species.

The masked bobwhite formerly occupied grassland habitat in southern Arizona (Goodwin and Hungerford 1977). It was extirpated in Arizona about 1900, but persists in Sonora, Mexico. In 1968, and periodically thereafter, it was reintroduced into Arizona using offspring from wild Sonoran stock. Its present status in the wild is precarious (Gabel 1986).

CHARACTERS AND MEASUREMENTS

The bobwhite is a small, rotund bird with rounded wings and a short, square tail. Its background color is reddish brown on the sides and gray-brown on the back and tail; it is white or buffy on the breast and belly, with pronounced dark vermiculations (wavy, irregular markings) on the belly feathers. White edges and dark bars and vermiculations on various body and wing feathers create an overall mottled appearance. The lower legs and feet are unfeathered. The beak is black, and the feet and legs are gray. The sexes are similar in shape and body size, but differ in the color of facial stripes and throat.

Plumage

Variations in plumage color and pattern that are unrelated to age or sex occur within and among populations and races. These variations, however, are neither consistent nor striking enough to permit the identification of individuals with a particular region or race, except for the pronounced difference between the masked bobwhite and other races north of Mexico. Distinct color variations occasionally occur among wild populations and may persist a few generations before disappearing.

The most widely recognized color variation is the Tennessee red quail, which was discovered in the 1920's on Ames Plantation in Fayette and Hardeman Counties of western Tennessee (Stoddard 1931). The plumage of this color phase generally lacks white markings in the feathers, with the throat and eyestripe being black. The color phase was propagated in captivity and remains today in at least a few captive flocks.

The masked bobwhite, with its uniformly reddish breast and belly and black face, resembles the Tennessee red color phase. However, this race is distinguished by pronounced white markings in feathers of the back. White or yellow birds, not necessarily albinos, occasionally occur in the wild. In the late 1950's a white bird was observed in the wild with a covey of normal birds in southern Illinois. Its plumage was white, but the legs, beak, and eyes were normal, implying a genetic basis other than albinism.

Weight

Newly hatched chicks weigh from about 6 to 7 g after the natal down has dried (Stoddard 1931). Weight gains are rapid, with juveniles approaching adult weight (about 160+ g) in 12 to 15 weeks.

Mean weights of mature bobwhites vary among regions, generally showing a clinal trend with larger birds occurring in northern or colder regions (Stoddard 1931). In midwestern and prairie regions, body weights during winter typically range from 185 to 200 g (Robinson 1957, Schultz 1959, Kabat and Thompson 1963, Robel and Linderman 1966, Robel 1969). At the other extreme, Florida bobwhites weigh about 148 to 15[illegible] g (Loveless 1958, Dabney and Dimmick 1977). Tennessee birds, geographically intermediate, are intermediate in weight also (170 g) (Dabney and Dimmick 1977).

Body weight is seasonally cyclic in bobwhites in most of their range. Weight increases during fall, peaks in midwinter, and declines through the

spring (Robinson 1957, Robel and Linderman 1966, Robel 1969). Robel and Linderman (1966) reported that Kansas bobwhites increased in weight from March to April, the last month sampled in their study. Robinson (1957) noted that weights were lowest in June and July for the sample of Kansas bobwhites he examined. Dabney and Dimmick (1977) demonstrated that body weight was positively correlated with stored body fat. For each 1-percent increase in fat, body weight increased about 1.2 g. Percent body fat also varied clinally, with the fattest birds occurring in cold climates, and seasonally, with body fat declining from midwinter to spring (Robel 1969, Dabney and Dimmick 1977). Thus, when normal values have been established for a geographic region and season of year, body weights may be useful for evaluating physiological condition of bobwhites (Dabney and Dimmick 1977).

It is important to recognize that within a population, body weight may vary among individuals as much as 10% to 15% above or below the mean without indicating nutritional deficiency or stress. Conversely, rapid weight loss of 17% to 29% caused by food deprivation may result in death (Gudlin et al. 1988).

Sex Determination

Plumages of northern bobwhites exhibit moderate sexual dimorphism. Sexes can be readily distinguished for birds in hand as early as 8 to 10 weeks; at this time sex can also be determined with little difficulty at close range in the field. The chin, upper throat, and eye stripes are white in the male (Fig. 4), whereas these markings are buffy in females. Middle wing coverts of males display fine, black, sharply pointed undulations, which sharply contrast with adjacent colors on the feathers. Feathers of the middle wing coverts of females have wide, dull-gray bands that lack distinct contrast (Thomas 1969). The base of the lower mandible is uniformly black (distinguishable at 6 to 8 weeks) in males and yellow in females (Loveless 1958).

Age Determination

Chicks are covered with down at hatching. Chestnut color predominates on the top of the head, back of the neck, and middorsal region (Johnsgard 1973). The belly and throat are gray or pale buff. A thin black stripe extends posterior to the eye down the short neck. Beak and legs are pinkish yellow. Juvenal plumage develops quickly, and by 2 weeks of age the wing feathers are sufficient for short flight.

The upper greater primary coverts of immature bobwhites are dull brown with buffy tips, and are tapered (Fig. 4). orresponding feathers of adults

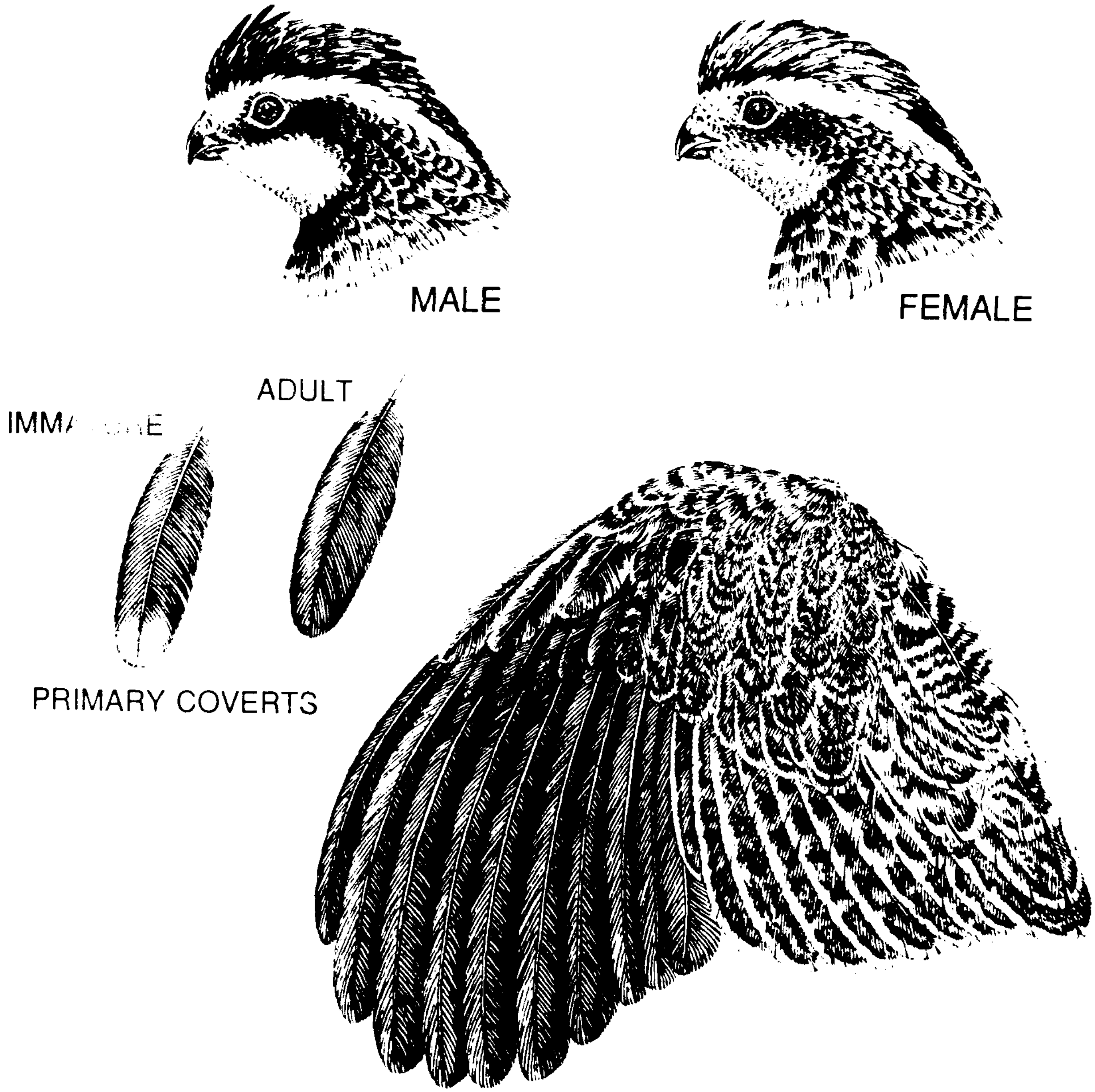

Figure 4. Sex and age characters of northern bobwhites showing a comparison of facial patterns in adults (top), and differences in primary coverts between adults and immatures

are uniformly gray or gray-brown, shiny, and have broadly rounded tips. The outer 2 primaries (P9 and P10) are pointed and dull brown in immatures, whereas they are rounded and grayish in adults. The wing characteristics of immatures serve as clearly evident indicators of age until near the completion of their first breeding season.

An estimate of the age of a bobwhite in days can be obtained for birds in the process of replacing juvenal primaries (Table 1). This method relies upon the replacement and growth of primaries 1 through 8. It is valid to about 150 days posthatching, when P8 has been replaced and is fully grown (Petrides and Nestler 1952). Age data derived from this technique can be quite useful for backdating nesting chronology for the previous breeding season.

Table 1. Age (in days) of juvenile bobwhites based upon molt and regrowth of primaries 1-8 (from Petrides and Nestler 1952)

	Primary Number							
Status	P1	P2	P3	P4	P5	P6	P7	P8
Dropped	28	35	42	47	54	62	74	101
1/4 grown	33	42	47	53	60	68	83	111
1/2 grown	41	47	51	57	65	74	93	119
3/4 grown	45	52	56	62	73	82	105	127
Fully grown	56	58	62	73	85	103	124	150

POPULATION ATTRIBUTES

Animal populations exhibit species-specific characteristics or attributes that limit or influence their response to management practices and ecological events, such as predation, weather, and land use changes. These attributes include behavioral characteristics such as monogamy, covey organization, family-rearing patterns, home range, and movement patterns. They also include demographic characteristics such as sex and age ratios, birth rates, and death rates. It is important to understand these characteristics and the degree to which they limit or define suitable management practices.

The Covey

Beginning about midsummer and continuing through early spring of the following year, bobwhites are spatially distributed in small, loose aggregates

of individuals. These aggregates initially form as broods with their parents. Other adult birds, mainly unsuccessful breeders, attach themselves to these broods as the broods travel within their late-summer home ranges (Stoddard 1931). Occasionally broods of different ages will coalesce and travel as a unit. As autumn progresses, these aggregations lose their identity as broods, and are more correctly called coveys.

In sparse populations, a covey may remain isolated from other coveys for long periods of time, particularly where habitat suitable for covey home ranges is limited and disjunct. Where bobwhite populations are moderately dense to dense, coveys frequently share home ranges with 1 or more other coveys. Under these circumstances, coveys often mingle with others during feeding activities or when they simultaneously seek the same escape cover (Yoho and Dimmick 1972a). This commingling typically results in a shifting of individuals among coveys so that when the birds redistribute themselves, the composition of individuals in a covey may be markedly different than it was prior to the mixing. Yoho and Dimmick (1972a) documented frequent shifts of individual quail among coveys in a dense population in western Tennessee. They estimated that an average covey of 13 birds would lose and gain a bird every 3 days. Lehmann (1984) documented more than 100 transfers of singles and groups among coveys in the Rio Grande Plain of Texas.

Covey size has been observed to fluctuate irregularly as winter progresses (Stoddard 1931, Rosene 1969, Yoho and Dimmick 1972a), which further indicates that covey composition is highly fluid. This ready tolerance for "new" individuals or groups in a covey most likely facilitates survival. By coalescing, coveys maintain an appropriate size as winter mortality brings about the annual population decline. Lehmann (1984) postulated that cumulative changes represent movement toward the goals of median covey size and equal sex balance within a covey.

Coveys may range in size from 5 or 6 birds to 26 or more. Occasional groups of 30+ individuals probably represent 2 or more coveys that are temporarily sharing a food or cover resource. Mean covey size varies among years, seasons of the year, and location, but typically ranges from 10 to 16 birds for a given area or year. Rosene (1969), for example, reported an average of 14.3 birds for 2815 coveys from 1947 to 1958 in South Carolina and Alabama, which is predominantly Coastal Plain habitat. Mean covey size ranged from 12.0 to 16.3 birds for specific areas. In south Texas rangeland, coveys

averaged 10 to 11 individuals, with a slight increase from fall to winter (Lehmann 1984).

In west Tennessee, on an 850-ha (2100-acre) area of cultivated farm, forest, and idle land, 1,696 covey flushes were counted in December from 1966 to 1988 (R. W. Dimmick, unpubl. data). Mean covey size was 13.1 birds for the 22-year period, and the population size ranged from approximately 900 to 3200 birds Mean covey size varied proportionally to population size, but with a much lower magnitude (11.6 to 14.6 birds/covey). Covey size declined about 1 bird per covey from December to March during the 1967-1980 study period (Exum et al. 1982). In southern Illinois, on an area exploited by hunters and characterized by somewhat harsher winters than in west Tennessee, Roseberry and Klimstra (1984) reported a decline in covey size from 13.4 birds in early November to 9.9 birds in late March, most of this occurring by early January. Ellis et al. (1969b) noted a decline in mean covey size from 16.7 in autumn to 8.9 in March on a hunted area in southern Illinois.

Population Density

Viable bobwhite populations may exist at density levels at or below 1 bird/40 ha (100 acres), though such sparse populations over large areas offer little or no opportunity for harvest. Guthery (1986) considered a density of 1 bird/2.5 ha (1 bird/6 acres) a very poor population on Texas rangeland. Elsewhere, that density may be fair to average. At the other extreme, population densities exceeding 2 bobwhites/ha (0.8 bird/acre) have been measured several places for at least short periods of time. Bobwhite densities of 2.5 to more than 4 birds/ha (1 to 2.4 birds/acre) were reported in Texas (Guthery 1986), and densities of 5.8 to 7.8/ha (2.4 to 3.2 birds/acre) were recorded for 3 consecutive autumns on a small area in northern Florida (Kellog et al. 1972). The December bobwhite population on a managed unit of Ames Plantation in west Tennessee exceeded 3 birds/ha (1.2 birds/acre) on 4 occasions from 1966 to 1972.

Roseberry and Klimstra (1984) summarized population densities for the bobwhite throughout portions of its range, utilizing studies of at least 6 years duration. About half of these studies reported densities from 0.39 to 0.65 bird/ha (0.16 to 0.26 bird/acre), with extremes from 0.14 to 1.64 birds/ha (0.06 to 0.66 bird/acre).

Regional patterns of density. By ecological region, highest densities typically occur in the Southeast Coastal Plain (Rosene 1969, Kellog et al.

1972), the plains of south Texas (Guthery 1986), and mixed row crop and forest lands of the mid-South (Dimmick 1974). However, stability of population densities varies significantly among these regions and is influenced variously by weather (and its effect on the habitat) and land use.

Striking irruptions and declines are most often observed along the southwestern periphery of the bobwhite's range (i.e., Texas and Oklahoma) where annual rainfall varies dramatically. Bobwhite numbers may exceed 2 birds/ha (0.8/acre) in years of high density, and decline to less than 1 bird/40 ha (1.0/100 acres) in low-density years. Jackson (1962) and Lehmann (1953) attributed these wide fluctuations to rainfall patterns and their effect upon habitat. Annual precipitation is usually adequate in the middle South and southeastern states, and population density seldom fluctuates widely in response to rainfall. For example, on 850 ha (2100 acres) of land managed for bobwhites in western Tennessee, the population density ranged from about 1.1 to 3.7 birds/ha (0.4 to 1.5 birds/acre) over 22 years (R. W. Dimmick, unpubl. data) (Fig. 5), a much smaller magnitude than that reported by Jackson (1962) for northwest Texas (Fig. 6). Weather was believed to play only a minor role in regulating density on the Tennessee study area, whereas land management practices were highly significant (Exum et al. 1982).

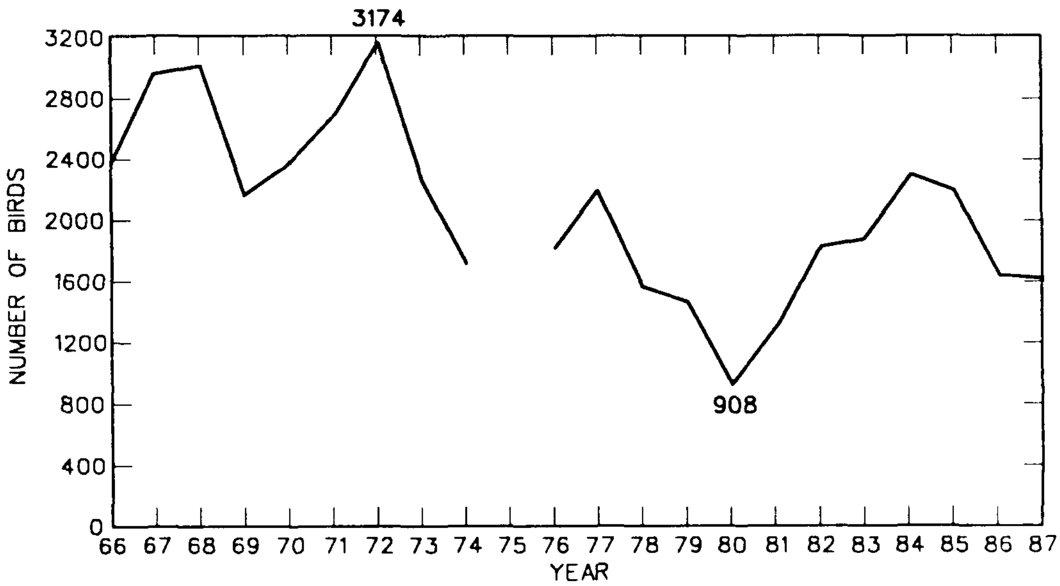

Figure 5. Annual fluctuations in numbers of northern bobwhites on Ames Plantation, Fayette County, Tennessee, December 1966-1987

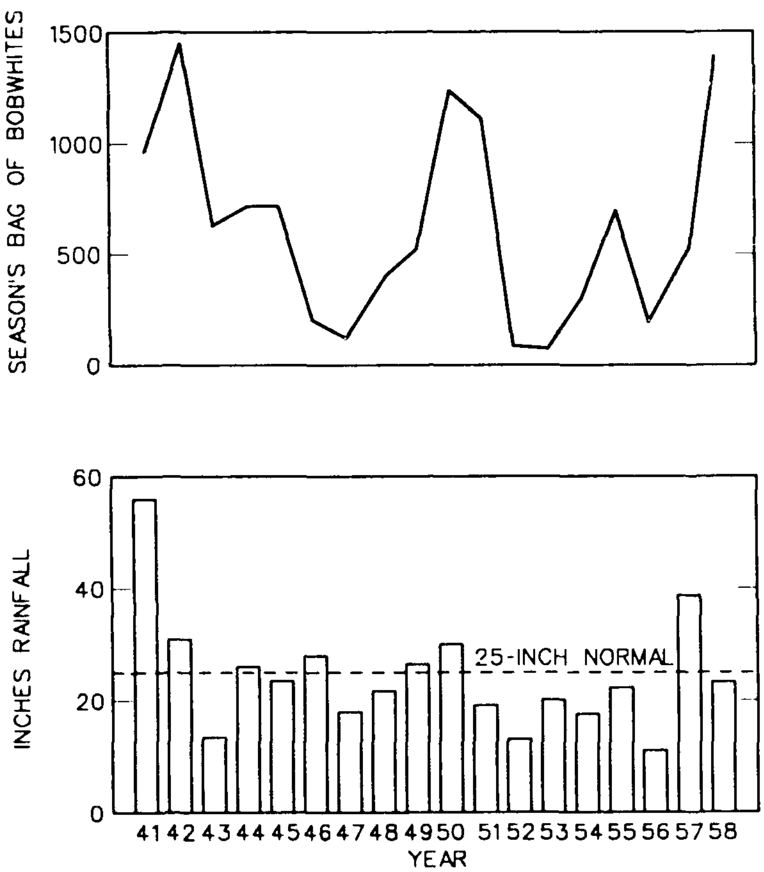

Figure 6. Irruptive population fluctuations of bobwhites in northwest Texas, 1941-1958, and annual precipitation during that period (from Jackson 1962)

<u>Seasonal patterns of density</u>. The annual cycle of numbers is generally similar to that exhibited by most temperate-zone birds, i.e., numbers peak at or near the end of the breeding/brood-rearing season and decline from autumn through late spring to a low point just prior to the onset of hatching of the annual crop of young. The pattern of change, however, varies moderately among regions. In the Midwest, substantial mortality accrues during the hunting season, typically October through December; Roseberry and Klimstra (1984) measured an average harvest of 43.8% of the prehunt population in southern Illinois during 1954-1972. However, the instantaneous weekly mortality rate increased markedly from late fall to early spring in an unexploited population in southern Illinois (Roseberry 1979). These data suggest that in the Midwest, hunting shifts the mortality schedule forward from late winter to fall, particularly where hunting begins as early as November and ends before

mid-January. In much of the southeastern United States and Texas, hunting is conducted through February (Appendix A), at which time winter is nearly ended. Thus, hunting mortality continues throughout the period when quail are also suffering losses caused by winter weather and reduced food and cover. Consequently, it is difficult to distinguish mortality caused by hunting from mortality caused by other factors unless an independent assessment of hunter harvest is made.

Special circumstances may also alter normal patterns of mortality. In northwest Texas, Jackson (1962) observed severe die-offs of a dense bobwhite population beginning in December of a year characterized by extreme drought; range sites were also overgrazed. Starvation was clearly indicated as the cause of the die-off, as many emaciated birds appeared in hunters' bags the opening week of the hunting season. Therefore, hunting had little influence on the pattern of mortality for that particular circumstance.

Sex Ratios

Bobwhites are monogamous for at least the breeding season. Consequently, a sex ratio approximating 1:1 is most favorable for maximum productivity.

The sex ratio of juveniles during fall varies only slightly from 1:1 and favors neither sex consistently. Among adults, however, males consistently comprise a significant majority. Roseberry and Klimstra (1984) examined more than 100,000 bobwhites harvested in southern Illinois from 1950 through 1979. Among juveniles, males ranged from 46.5% to 52.8%, comprising 50.3% of the entire sample. Males comprised 59.6% of all adults, varying among years from 49.8% to 64.9%. Stoddard (1931) also noted a preponderance of cocks among 20,000 birds examined in the north Florida-south Georgia region, but he did not distinguish between adult and juvenile quail when calculating sex ratios. Numerous other reports have noted a balanced sex ratio among juveniles and a preponderance of males among adults. These data strongly imply that females encounter significantly greater mortality than males between winter and fall.

Age Ratios

Bobwhites are short-lived birds, and their high turnover rates are exemplified by a preponderance of juveniles in the immediate postbreeding population. Typically, juvenile:adult ratios approximate 4:1 or higher in years of normal production. Jackson (1969) reported a ratio of 4:1 for 42,460 bobwhites harvested on the Rolling Plains of northwest Texas during 1950-1964.

Roseberry and Klimstra (1984) reported a ratio of 4.9:1 for more than 100,000 birds harvested during the autumn hunting season in southern Illinois. The ratio varied annually from 3.3:1 to nearly 7:1, based on yearly samples greater than 1300 birds. This range of values encompasses most of the age ratios reported from across the bobwhite's range (Rosene 1969). It is generally assumed that high ratios of juveniles to adults in the fall population indicate a successful production year for the population. However, Jackson (1969) rejected this assumption; he concluded that deaths of the parent generation operated to maintain a high ratio of young to adult even in years of low productivity.

Home Range and Movements

Bobwhites characteristically are sedentary birds, spending their short lives within an area often encompassing no more than 5 to 40 ha (12.5 to 100 acres). Home range size may be negatively correlated with habitat quality (i.e., bobwhites living in environments that provide all the bird's needs in close juxtaposition, and which are generally stable from year to year, have the smallest home ranges).

Home ranges of 8 bobwhite coveys in northeastern Oklahoma averaged 4.4 ha (11 acres) and did not vary among fall, winter, and spring, although home ranges were smaller where population densities where higher (Wiseman and Lewis 1981). Coveys in southern Illinois farmlands maintained home ranges of about 9 ha (22.5 acres) in August and September, expanded their ranges to more than 16 ha (40 acres) in October, and then reduced their ranges to about 9 ha in November (Urban 1972). Urban (1972) suggested that the October expansion served to increase contact between coveys. Winter home ranges for 5 coveys in west Tennessee varied from 4.0 to 11.7 ha (10 to 29 acres) and averaged 6.8 ha (17 acres) (Dimmick and Yoho 1972). Five unmated males had an average summer home range of 6.9 ha in west Tennessee (Saunders 1973). In southern Illinois, Urban (1972) noted distinctly different home range sizes for unmated males (16.7 ha [42 acres], n = 9); mated males (7.6 ha [19 acres], n = 11]; nesting females (6.4 ha [9 acres], n = 5); and postnesting females (15.6 ha [39 acres], n = 4). These home ranges were defined by radiotelemetry and were based on many locations.

Most other studies of bobwhite home ranges have relied upon leg-banded birds that were subsequently recaptured or shot by hunters (Duck 1943, Lehmann 1946a, Murphy and Baskett 1952, Lewis 1954, Loveless 1958). Their evaluations

of daily and seasonal mobility of bobwhites were necessarily expressed in linear terms, as few birds yielded more than 2 or 3 locations. These studies generally verified the rather sedentary nature of bobwhites; most reported seasonal movements of less than 0.4 km (0.24 mile) and annual movements of 0.8 to 1.6 km (0.5 to 1 mile). However, there is ample evidence that bobwhites are capable of moving long distances when survival requires it. Duck (1943) reported that 11 birds banded in upland areas of northwestern Oklahoma in late summer had moved an average of 16.2 km (9.7 miles) by December. The longest distance moved was 43 km (25.8 miles) for a bird banded September 8 and recovered December 2. These unusually long movements were attributed to the need to find good winter cover with the approach of severe weather. Lehmann (1984) documented records of birds taken 20 and 65 miles from where they were banded in southern Texas.

There may also be an inherent tendency for bobwhites in some populations to increase mobility during autumn without respect to weather or obvious habitat changes. This behavioral trait is often referred to as the "fall shuffle" and is generally understood to be local, unoriented movement of coveys. Murphy and Baskett (1952) noted this in Missouri quail, though linear distances moved were not great. The expanded October home ranges of bobwhites in southern Illinois, which Urban (1972) termed "behavioral" rather than habitat or weather stimulated, may also be an expression of the fall shuffle. Autumn movements of 10 bobwhites banded by Loveless (1958) in south-central Florida pine flatwoods were much greater than those of birds in Illinois and Missouri. Those birds moved from 3.3 to 15.8 km (2 to 9.8 miles), with an average distance of 10 km (6.2 miles). Loveless (1958) concluded that these extreme movements were not in response to weather and habitat changes, nor were they unoriented. Rather, they were thought to represent movement away from dense population centers, even though this entailed moving to habitat of poorer quality.

Breeding Biology

Bobwhites characteristically are monogamous for at least one breeding season, breed during their first year of life, rear only a single brood each year, and remain as a family unit with both parents participating in brood rearing. The hen is an indeterminate layer capable of renesting several times during the species' long nesting season. The result of these parameters is a

species with high biotic potential (i.e., capable of producing many young in a breeding season).

Reproductive chronology. The first notable signal that breeding season is under way is the "bobwhite" call issued by the male. The first date of calling occurs earliest in the deep South. Rosene (1969) reported calls as early as January and February in Georgia and Florida, and Lehmann (1984) reported calling in February in south Texas. In west Tennessee, bobwhites form pairs within coveys, and males call as early as mid-March, though coveys generally remain intact until April. Bobwhites initiate calling about mid-March in Kansas (Robinson 1957) and as late as mid-April in Missouri (Stanford 1952).

Formation of pairs occurs prior to and during the breakup of the coveys (Parmalee 1955), typically late March through April at various latitudes. Pair formation has been reported as early as February in southern Texas (Lehmann 1984). Even though birds are paired by the end of April, the territorial whistling of males continues well into summer, peaking in intensity as late as the latter part of June through July (Saunders 1973).

Nest building, egg laying, and incubation are most intensive in May, June, July, and August (Stoddard 1931, Stanford 1952, Robinson 1957, Dimmick 1971, Klimstra and Roseberry 1975). High rates of nest destruction and subsequent renesting produce asynchronous nesting patterns from early to late in the season. At any time from May through August, individual hens may be nest-building, laying, incubating, or rearing young, and both mated and unmated males continue to whistle. The last chick may be hatched as late as October, but this event varies widely among years (Klimstra and Roseberry 1975). Hatching of the last chick has been reported in November and December in south Texas (Lehmann 1984). In most years, the proportion of bobwhite chicks hatching after the end of August is insignificant.

Nest construction. Bobwhites construct their nests on the ground in shallow, saucer-shaped depressions that are formed with the feet and beak (Stoddard 1931). Either or both sexes may participate in nest construction. Stems and leaves of dead grass or pine needles located within easy reach of the nest depression are woven into a hollow, covered structure about the size of a softball (Fig. 7). Usually the canopy is complete, with one end open for access. However, some nests have no top at all, which exposes the eggs to view. The nests typically are constructed at the base of a clump of

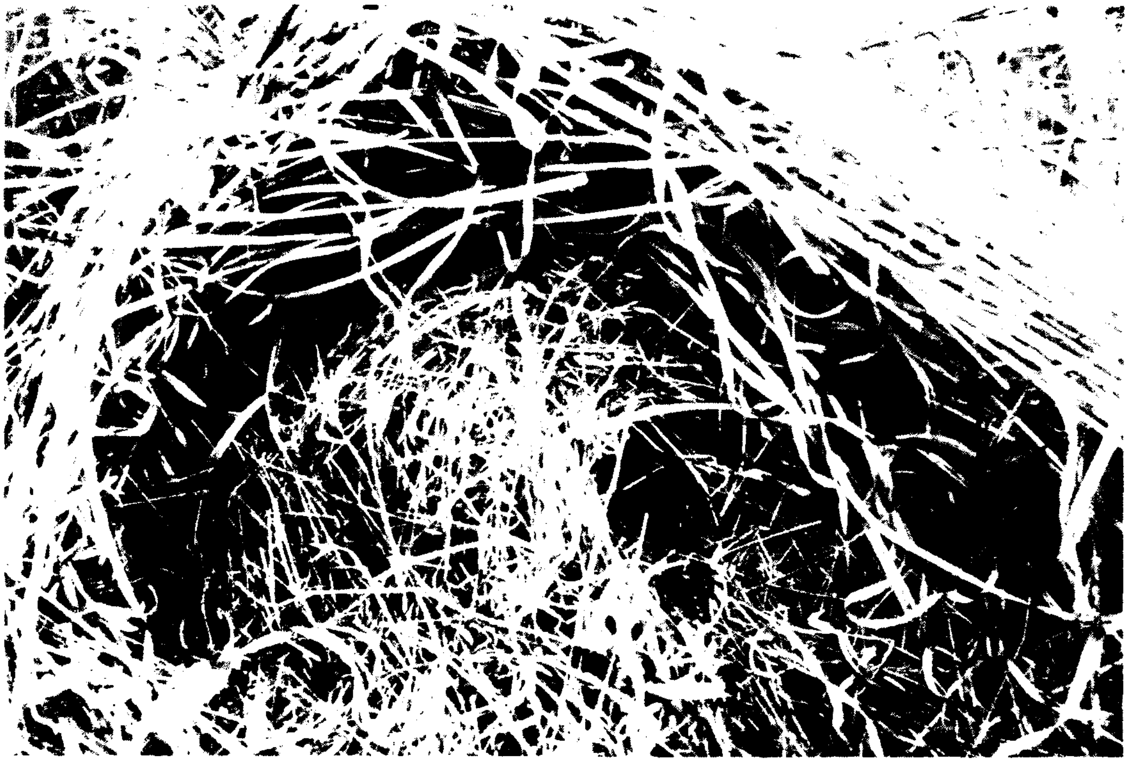

Figure 7. Northern bobwhite nest constructed in broomsedge (cover pulled back to show nest characteristics)

vegetation, such as broomsedge (*Andropogon virginicus*), which provides additional concealment to the nest structure. Construction may require 4 hours or more, and may be accomplished over 2 days.

Egg laying. Bobwhite eggs are white, bluntly rounded on the end that will be pipped open at hatching, and pointed at the opposite end. Normal eggs weigh from 8 to 10 g (Stoddard 1931).

Egg laying normally begins within a day after the nest is constructed. Eggs are laid at a rate of 1 per day, though occasionally a day is skipped (Stoddard 1931). This skipping may account for the rate of 1 egg per 1.2 days reported by Klimstra and Roseberry (1975) for a small number of clutches in southern Illinois. Occasionally eggs may accumulate in a nest at a rate greater than 1 per day. This likely is the result of 2 hens laying in the same nest (Klimstra and Roseberry 1975).

Clutch size. The number of eggs per completed clutch varies slightly among areas but generally averages 12 to 14 (Stoddard 1931, Simpson 1972, Dimmick 1974, Klimstra and Roseberry 1975, Lehmann 1984). Mean clutch size declines slightly as the nesting season progresses; Figure 8 shows a hatched

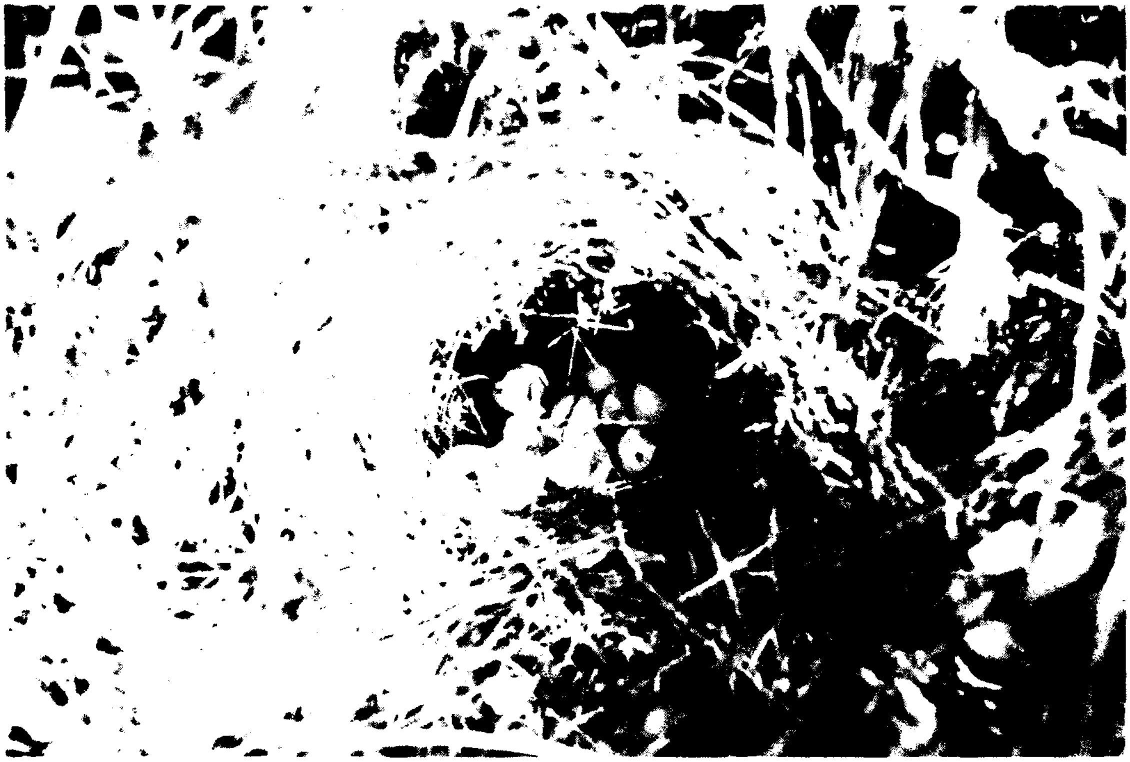

Figure 8. Bobwhite nest with hatched clutch of eggs

clutch of eggs. Bobwhites may lay fewer eggs in renesting attempts, thus lowering average clutch size in late summer when a large proportion of clutches may be second or third attempts at nesting.

Incubation. The incubation period for bobwhites is approximately 23 days. Females most commonly incubate the eggs, but Klimstra and Roseberry (1975) observed males incubating at 28 (26.4%) of 106 nests. Some of those males assumed incubation duties after a female had initially incubated. Stoddard (1931) also noted this behavior. In west Tennessee, about 15% of the clutches were tended partially or entirely by males (R. W. Dimmick, unpubl. data). The implications of male incubation are not well understood, but 2 explanations are likely: (1) the female may have died, leaving the male solely responsible, or (2) the female may have established a new nest, laid a second clutch, and incubated it, leaving the first clutch to be incubated by her mate. Either or both cases may occur and would serve to enhance productivity. Stanford (1972a) documented cases of females laying, incubating, and hatching 2 sequential clutches in a single nesting season, thus lending support to the second hypothesis.

Renesting. Second or third nesting attempts following destruction of prior nests are characteristic, but the extent to which they occur is not well quantified. Dimmick (1974) suggested that estimating productivity per hen based upon nest success rates was inappropriate because the extent of renesting could not be measured directly. The extent of renesting likely varies among years (Klimstra and Roseberry 1975) and may be positively correlated with productivity (Dimmick 1974).

Care of young. Both parents participate in rearing the chicks and are very protective of them until they are several weeks old. The brood may remain in the nest up to several hours after the last chick has hatched, but once departed, the family no longer has any attachment to the nest. The chicks alternate between feeding and brooding, with either parent brooding them (Stoddard 1931). Both parents respond vigorously to the chick's peeping distress call by rushing toward the perceived aggressor or exhibiting the "broken wing" distraction display. Chicks may fly very short distances at 2 weeks, and by 8 weeks they have achieved nearly the size and mobility of the adult.

Productivity

Bobwhites are highly productive, and autumn populations are comprised of 70% to 80% young of the year (Jackson 1969, Rosene 1969, Roseberry and Klimstra 1984). The level of production is the summation of large clutches, egg fertility rates >90%, and long nesting seasons that permit ample time for renesting. These positive aspects compensate for moderate to low rates of nest hatching success (the percentage of nests that hatch 1 or more eggs). Of 766 nests studied in west Tennessee during 1967-1974, only 23% hatched, varying among years from 17.1% to 36.6% (Dimmick 1974). Similarly low hatching rates were observed elsewhere: Illinois - 33.7% of 863 nests (Klimstra and Roseberry 1975); Georgia - 25.1% of 680 nests (Simpson 1972); Texas - 46% of 87 nests (Lehmann 1946b). Hatching success varies significantly among years and among areas, but may not correlate well with the size of the postbreeding population.

Dimmick (1974) concluded that the total number of nests constructed on his study area in west Tennessee was the best predictor of the size of the postbreeding population ($r^2 = 0.65$), regardless of hatching rate. Klimstra and Roseberry (1975) noted that annual production of chicks was almost equally dependent on both the number of nests built and their rate of success. The

total number of nests probably reflects both the size of the breeding population and the degree of renesting that occurs. Both of these parameters are regulated by the availability and quality of winter food and cover through their influence on the condition of bobwhites entering the breeding season. The hatching rate of nests, however, is determined by events occurring during the breeding season and is not necessarily related to winter habitat quality. Because hatching rate is often poorly correlated with fall population size, it may be hypothesized that events that directly affect hatching success during the breeding season (predation, nest desertion) are less influential on the production of young than is the quality of winter food supplies and cover.

One poorly known quantity in the bobwhite's productivity equation is the survival rate of chicks and those factors that affect it. No studies of bobwhite chick survival rates have quantified this aspect or defined its variability among years.

Mortality

In a stable population of any species, mortality rates will balance the productivity rates. Consequently, the normally high annual productivity of 70% to 80% in bobwhites is matched by an equivalent annual mortality rate. Although mortality rates and productivity rates vary somewhat among regions and among years, the variation is not great. High mortality rates occur in populations that are not exploited, as well as in those that are heavily exploited by hunting, predation, or both (R. W. Dimmick and J. C. Cole, unpubl. annual report to Tennessee Wildlife Resource Agency, 1990). Population density may be dramatically lowered temporarily by severe weather such as drought or winter storms, or permanently by major losses of habitat; however, even in these situations, mortality rates will tend to restabilize at a characteristic 70% to 80% level once the population has adjusted to its new habitat-imposed level.

Hunting. Hunting is a significant cause of death in many bobwhite populations. Roseberry and Klimstra (1984) reported that hunters removed 17% to 67% (including crippling losses) of the prehunt population on a study area in southern Illinois; the area had a mean annual harvest rate of 42.5% from 1954 through 1972. The season length in southern Illinois ranged from 31 to 49 days and ended before January, and state hunting regulations were typical for the Midwest. Season length was much more restrictive than is common in southern states, where the length of the hunting season is 2 to 3 times

greater, continuing to the end of February and into early March in some states. Harvest rates in southern Texas range from 40% to 60% (Lehmann 1984).

Roseberry and Klimstra (1984) concluded that more than 75% of the variation in annual harvest rates could be accounted for by hunting pressure (the number of gun-hours expended). However, the annual variation in season length during their study was not great enough to determine if season length influenced total hunting pressure. Data from later years in southern Illinois suggested that extending the hunting season to January 15 increased harvest by 20% (Roseberry and Klimstra 1984). Unfortunately, though numerous studies address the issues of hunter effort, hunter success, and crippling losses, few have measured the amount of the prehunt population removed by the harvest. The limited information available suggests that hunting may remove from 0 to 60% of the prehunt fall population across a broad range of circumstances.

Predation. Predation upon eggs is high but occurs during a time when its effects can be rapidly compensated for by renesting. Although difficult to measure, predation upon chicks may be substantial, as the small birds with limited mobility would be subject to a wide variety of predators. It is unlikely that an entire brood would be captured by a predator during a single attack. However, disruption of the family unit could leave those chicks surviving the attack vulnerable to exposure or later predation. Chicks killed by predators are unlikely to be replaced by subsequent reproduction during the current breeding season.

Predation upon adult and fully developed young bobwhites can be accomplished efficiently by only a few species of predators. The most efficient of these is the Cooper's hawk (*Accipiter cooperii*) (Stoddard 1931). Stoddard was convinced that Cooper's hawks were highly detrimental to bobwhites, though his examination of 9 birds killed on southern plantations yielded remains of only 1 bobwhite. Mueller (1989) reported that quail comprised 73% of all food items brought to 2 Cooper's hawk nests at Tall Timbers Research Station in northern Florida; predation on bobwhites was high from mid-February to mid-April and again in June. This area supports a high-density quail population, and elsewhere, Cooper's hawks are not likely to prey on quail to this extent.

Other avian and mammalian predators occasionally remove mature bobwhites. However, their combined effect on the quail population is minimal and is outweighed by their reduction of other predators, particularly rodents and snakes, which compete with bobwhites for food and/or consume their eggs or

young. Major predators on bobwhite eggs, chicks, and adults are listed in Table 2.

Table 2. Species most commonly reported to prey on bobwhites

Predator Species	Eggs	Chicks	Adults*
Mammals			
Coyote (*Canis latrans*)	X	X	X
Domestic dog (*C. familiaris*)	X	X	X
Gray fox (*Urocyon cinereoargenteus*)	X	X	X
Red fox (*Vulpes vulpes*)	X	X	X
Bobcat (*Lynx rufus*)		X	X
Domestic cat (*Felis domesticus*)	X	X	X
Striped skunk (*Mephitis mephitis*)	X		
Badger (*Taxidea taxus*)	X		X
Weasels (*Mustela* spp.)		X	X
Mink (*M. vison*)		X	X
Raccoon (*Procyon lotor*)	X		X
Opossum (*Didelphis virginiana*)	X		
Cotton rat (*Sigmodon hispidus*)	X		
Birds			
Cooper's hawk (*Accipiter cooperii*)		X	X
Sharp-shinned hawk (*A. striatus*)		X	X
American crow (*Corvus brachyrhynchos*)	X		
Great-tailed grackle (*Quiscalus mexicanus*)	X		
Reptiles			
Coachwhip (*Masticophus flagellum*)	X	X	
Whipsnake (*M. taeniatus*)	X		
Corn snake (*Elaphe guttata*)	X	X	
Rattlesnakes (*Crotalus* spp.)	X	X	X

Sources: Stoddard 1931, Rosene 1969, and Lehmann 1984.

* Except for accipiters, predation on adult bobwhites is usually the result of capturing incubating birds on the nest.

Predation and hunting are intercompensatory agents of mortality (i.e., hunting is generally regarded as a replacement for natural predators as a mortality factor), particularly during autumn and early winter. In the absence of hunting, predation and other forms of mortality serve primarily to remove the surplus annual production, i.e., the number of bobwhites exceeding the habitat's carrying capacity. On 2 areas of farmland in middle Tennessee, bobwhite populations showed similar patterns of winter decline and subsequent

recovery on both a hunted and unhunted area (R. W. Dimmick, unpubl. data). Predation or other decimating factors may have compensated for hunting mortality on the unhunted area, thus reducing the population to carrying capacity.

Parasites. Wild bobwhites are commonly infected with gastrointestinal parasites. Cram (1931) identified 16 species of roundworms (Nematoda) in bobwhites throughout its range, and Jones (1931) found 5 tapeworms (Cestoda). Kellog and Prestwood (1968) identified 3 tapeworms and 8 roundworms from 71 quail shot in South Carolina, Georgia, and Florida. Blakeney and Dimmick (1971) reported 2 species of tapeworms and 2 roundworms from 140 quail shot in west Tennessee; 95% of the quail had at least 1 species of intestinal worm. McRae and Dimmick (1981) identified 2 more species of roundworms in a sample of quail from the same Tennessee population. Lehmann (1984) reported roundworms, tapeworms, and spine-headed worms (Acanthocephala) from south Texas.

The cecal worm (*Heterakis bonasae*) frequently has the highest rate of occurrence and the greatest intensity of infection in bobwhites. The incidence of occurrence reached 92% or greater in study areas in Florida, Tennessee, and Georgia (Kellog and Prestwood 1968, Blakeney and Dimmick 1971). The average number of worms per bird in these areas ranged from about 17 to 134, with some individuals harboring 400 to 700 worms. This parasite, even when present in large numbers, causes little or no apparent stress to wild quail. Some parasites of the gastrointestinal tract, however, may be pathogenic to heavily infested individuals. Among those reported to have been pathogenic in wild free-ranging birds are *Capillaria contorta* from the crop of wild quail (Cram 1930), *Dispharnyx nasuta* from the proventriculi of blue grouse (*Dendrogapus obscurus*) (Bendell 1955), and *Trichastrongylus tenuis* from the ceca of red grouse (*Lagopus lagopus*) of Great Britain (Cram 1931).

Some general principles of parasitism applicable to wild bobwhites are noted below.

(1) Parasite burdens tend to be higher in areas with higher densities of bobwhites (Kellog and Prestwood 1968, Dabney and Dimmick 1977).

(2) The number of species infecting a population is greater in dense populations of bobwhites than in sparse populations (Kellog and Prestwood 1968).

(3) Intestinal parasites are rarely significant causes of mortality or poor health in wild bobwhites. Dabney and Dimmick (1977) observed no correlation between the intensity of parasite infection and body fat of wild birds.

(4) Some parasites, while causing little direct damage to their host, may transmit highly pathogenic diseases. Examples include the implication of cecal worms in transmitting blackhead disease (*Histomonas meleagridis*) among wild turkeys (*Meleagris gallopavo*) (Kellog and Reid 1970, Davidson and Nettles 1988), and *Trichostrongylus* as a vector or cause of "grouse disease" in red grouse (Cram 1931).

Releasing pen-reared birds into wild populations of bobwhites may introduce parasites or diseases typically associated with domestic flocks. For example, bobwhites are susceptible to the protozoan that causes blackhead disease. This is a rather serious disease in bobwhites, with mortality rates greater than 50 percent (Davidson and Nettles 1988). Although blackhead occurs occasionally in wild bobwhites, it is far more prevalent in pen-reared birds. The reason for this difference is that pen-reared bobwhites tend to be infected with the cecal worm of domestic chickens, which transmits blackhead much more effectively than the cecal worm of wild quail. Thus, introducing the domestic chicken fecal worm into wild quail populations could enhance the spread of blackhead among wild quail.

Several external parasites have also been documented for bobwhites. These include mites (Acarina), ticks (Ixodoides), fleas (Siphonoptera), and flies (Diptera) (Lehmann 1984).

Diseases. Bobwhites are susceptible to a wide variety of diseases caused by viruses, bacteria, protozoa, and fungi. Several diseases have caused severe losses in captive flocks; these include ulcerative enteritis (bacterium), histomoniasis = blackhead (protozoan), and quail bronchitis (virus) (Davidson and Nettles 1988). However, diseases are rarely implicated as a limiting factor in wild quail populations (Davidson and Nettles 1988). Quail pox, a viral disease causing warty protuberances on the feet, mouth, and eyelids, occasionally has appeared in some southeastern bobwhite populations (Davidson and Nettles 1988). Although the incidence of pox infection has been relatively light in wild quail, there is recent concern that pen-raised birds may be locally important as vectors.

Pesticides. The close association of bobwhites with agricultural crops regularly places them at risk of death or disability from agricultural pesticides. Chicks are especially vulnerable because broods commonly use croplands as foraging areas. Pesticides commonly used for crop management include insecticides and herbicides; fungicides are also used on bean crops.

Insecticides are applied by spraying or misting from airplanes and ground machinery for leaf, flower, and fruit pests; they are also injected

below the surface for soil-dwelling insects. Organochlorines, such as dieldrin and DDT, are long-lasting in the environment, and many have been shown to cause long-term declines in bird populations because of their impact on reproduction. Some of these are banned or heavily restricted in the United States (White et al. 1990). Organophosphates and carbamates are quick-acting, short-lived, and do not accumulate in food webs (Stickel 1974). Their use increased as the organochlorines became increasingly restricted. However, some of these, such as Guthion, are extremely toxic to vertebrates and have caused some bird kills. Furadan in granular form is used for controlling soil insects in cotton and is extremely toxic to birds. Careless application may result in piles of this pesticide on the surface at the ends of cotton rows, where availability to bobwhites is greatest.

An important development is the use of synthetic pyrethroids as substitutes for the organophosphates. This family of insecticides is lower in toxicity than its predecessors, and should reduce the danger of insecticides to bobwhite.

Rodenticides may also present some hazards to bobwhite, but these compounds are much less commonly used than insecticides or herbicides. Rodent damage is typically sporadic or episodic. Consequently, rodenticides are applied "as needed" rather than as a standard cultural practice. As no-till agriculture increases, however, rodent control may become a more regular element of crop management. Zinc phosphide is an effective rodenticide used on grain baits; it is usually distributed by broadcasting but may also be applied beneath the surface with no-till planters. It is frequently used in orchards and pine plantations to control voles (*Microtus* spp.) and cotton rats (*Sigmodon hispidus*). Although zinc phosphide is toxic to bobwhites, it is unappetizing. Bobwhites largely rejected treated baits in feeding trials when they were presented along with untreated grains (Hines and Dimmick 1970).

Herbicides also include some formulations that are extremely toxic to vertebrates. Chloropicrin (Picfume) and methyl bromide (Meth-O-Gas) are highly toxic, and paraquat (Gramoxone) is moderately toxic. Gramoxone is commonly used as a "burn-down" herbicide in no-till agriculture. Roundup, a glyphosphate, is an acceptable substitute that is only slightly toxic.

Weather. Catastrophic weather events (e.g., blizzards, ice storms, and prolonged drought) wreak occasional, but unpredictable, havoc upon bobwhite populations. Severe blizzard conditions are characteristic of the upper Midwest and Plains region, often suppressing bobwhite numbers to extremely low

levels for several years duration. Kabat and Thompson (1963) concluded that quail populations declined dramatically any time a series of severe winters occurred in southern Wisconsin. In Missouri, winters of severe cold and snow were accompanied by high losses of breeders, low production of young, and reduced hunting success (Stanford 1972b). Above-normal snowfall in late winter and early spring in Illinois was related to reduced quail harvest the following autumn (Edwards 1972). Roseberry and Klimstra (1984) concluded that the most consequential weather factor for bobwhites in the Midwest was prolonged snow coverage of sufficient depth to cover a major portion of their food supplies.

Ice storms may occasionally blanket the countryside for up to 7 days in the upper and middle South. Icing in the South occurs less frequently than snow in the Midwest, but when it does occur it can be serious for bobwhites by reducing the availability of critical food supplies, weakening the birds, and increasing their susceptibility to predation.

Drought as a catastrophic weather event occurs most commonly along the southwestern fringe of the bobwhite's geographic range, particularly in Texas and Oklahoma. Its effect on bobwhites is primarily a reduction in food supply, which results in mass starvation (Lehmann 1984). For example, Kuvlesky (1990) reported a severe die-off (86% decline) that occurred over winter during a drought year on a 1134-ha (2800-acre) study area in south Texas. Severe drought in Missouri primarily affects egg laying and hatching, but hens may become emaciated and die on the nests (Stanford 1972b). In the deep South, such traumatic weather events occur less frequently than on the fringes of the bobwhite's range and usually produce less severe impacts upon the population.

HABITAT REQUIREMENTS

Ideal bobwhite range provides a diversity of herbaceous and woody habitat components. A variety of foods is required to meet the special requirements of growing chicks, breeding hens, and all sex-age classes during fall and winter. Cover requirements are also specific and seasonal. Cover that affords protection from weather, predators, and hunters is paramount in the fall, winter, and early spring. Good nesting cover consists of vegetation suitable for building the nest and concealing the nest and clutch of eggs.

The degree of interspersion of the components of food and cover is a major determinant of the quality of the bobwhite's habitat.

Over much of the bobwhite's range, water is rarely or never insufficient, and birds apparently obtain sufficient moisture from preformed water and dew (Stoddard 1931); thus, it usually is not considered in management plans. However, water may occasionally become critically scarce in the semi-arid southwestern portion of the range, and may limit the bird's distribution and/or abundance. When preformed water was limited and higher temperatures increased the need for evaporative cooling, bobwhites in southern Texas drank surface water to supplement oxidative water (Prasad and Guthery 1986).

Food

Bobwhites are predominantly seed eaters but also incorporate green leafy material, fresh fruits, and invertebrates into their highly varied diet. Food may be picked up from the surface of the ground, pulled from low-growing plants, or plucked from trees (Stoddard 1931). The primary species consumed varies among regions, but important general food types are fairly consistent across the bobwhite's range. The diet of the bobwhite varies seasonally, and to some extent among sex and age groups.

Variety. Stoddard (1931) described a diet including several hundred species of plant seeds, green vegetation, and invertebrates eaten by adult bobwhites sampled from Georgia, Florida, North and South Carolina, Alabama, Mississippi, and Tennessee. Plant material composed 85.6% of the diet, and animal matter made up the remainder. On a much more localized basis, Eubanks and Dimmick (1974) identified more than 178 food items consumed by bobwhites on a 1600-ha (3952-acre) area in western Tennessee. Food habit studies from other parts of the bobwhite's range are summarized in Rosene (1969). Major foods reported from several diverse geographic regions are listed in Table 3.

Despite their omnivorous, opportunistic feeding style, bobwhites tend to favor a few food groups for the major portion of their diet. For example, nearly 70% of the annual diet of bobwhites on Ames Plantation, Tennessee, consisted of only 10 of the 178 food items eaten (Eubanks and Dimmick 1974). One food, soybean (*Glycine max*), comprised 38% of the total diet.

Wild and cultivated legumes that are heavily used where they occur include soybeans, Korean lespedeza (*L. stipulacea*), common lespedeza (*L. striata*), partridge peas (*Cassia* spp.), bicolor lespedeza (*L. bicolor*), and beggarweeds (*Desmodium* spp.). Corn (*Zea mays*), sorghum (*Sorghum vulgare*),

Table 3. Major bobwhite foods reported from several geographic regions in the United States*,**

Southeastern Coastal Plains and Piedmont		
Beggarweeds	Ragweeds	Common lespedeza
Corn	Korean lespedeza	Partridge pea
Milk peas	Oaks	Sumacs
Bush clovers	Pines	Soybean
Cowpeas	Jewel-weeds	Dogwoods
Sweetgum	Wild beans	Sorghum
Hog peanut	Panic grasses	Black locust
Johnson grass	Wheat	Honeysuckles
Sassafras	Smartweeds	Vetches
Crab grass	Paspalums	Ash
Poor Joe	Bull grass	Grapes
Spurred butterfly pea	Doveweeds	Foxtail grasses
Cranesbill	Woodsorrels	Sericea lespedeza
Nutrushes	Bicolor lespedeza	Blackberries
Nightshades	Beggar ticks	Ground nut
American beautyberry	Sesbania	
Midwestern Agricultural Lands		
Korean lespedeza	Common ragweed	Partride pea
Wild bean	Beggarweeds	Goldenrod
Poor Joe	Fall white aster	Common ticklegrass
Beggarticks	Rushes	Sesbania
Wooly lespedeza	Daurica lespedeza	Sunflowers
Sweet clover	Ground cherry	Wild grape
Blackberries	Oaks	Sassafras
Ash	Sorghum	Corn
Yellow foxtail	Wheat	Crotons
Common lespedeza	Soybeans	Sumacs
Rolling Plains (Texas Panhandle and Western Oklahoma)		
Western ragweed	Erect dayflower	Texas croton
Rag sumpweed	Small wildbean	Sandlilly
Redroot amaranthus	Snakeweed	Common sunflower
Snow-on-the-mountain	Illinois bundle-flower	Panic grasses
Bluestem pricklypoppy		Fringeleaf paspalum
Showy partridge pea	Russian olive	
Fragrant sumac	Netleaf hackberry	Mesquite
Woolybucket bumelia	Common persimmon	Shin oak
Sorghum	Giant ragweed	Rough sumpweed

(Continued)

* Scientific names are given in Appendix B.

** Major references for each region: Southeast (Stoddard 1931, Rosene 1969, Landers and Johnson 1976); Midwest (Korschgen 1948, Robel 1964, Ellis et al. 1969a, Dumke 1982); Rolling Plains (Baumgartner et al. 1952, Jackson 1969, Tobler and Lewis 1980); and south Texas (Lehmann 1984, Koerth et al. 1986, Wood et al. 1986).

Table 3 (Concluded)

South Texas Plains		
Doveweeds	Hoary milkpea	Erect dayflower
Snow-on-the-mountain	Yellow woodsorrel	Ragweeds
Verbena	Texas millet	Wild rice
Fringed signalgrass	Switchgrass	Bristlegrass
Browntop millet	Witchgrass	Johnsongrass
Groundcherry	Spiny hackberry	Pricklyash
Wooly bumelia	Hackberry	Live oak
Paspalums	Cooperleaf	Dollar-weed
Slender evolvulus	Fringed signalgrass	Spreading panicum
Roundseed dicanthelium		

winter wheat (*Triticum aestivum*), various millets (*Panicum* spp.), and paspalums (*Paspalum* spp.) are important grasses. Doveweeds (*Croton* spp.) and ragweeds (*Ambrosia* spp.) are often substantial food items, as are acorns (*Quercus* spp.), flowering dogwood (*Cornus florida*), and a variety of soft fruits (Stoddard 1931, Lay 1965, Jackson 1969, Rosene 1969, Landers and Johnson 1976, Lehmann 1984).

Invertebrates, primarily insects, are also an important part of the bobwhite's diet. Stoddard (1931) found that insects were especially consumed during the spring and summer nesting and brood-rearing seasons in the Southeast. Primary invertebrate foods, listed in order of importance, were grasshoppers (Orthoptera), beetles (Coleoptera), true bugs (Hemiptera), ants (Hymenoptera), spiders (Arachnida), and occasionally snails (Gastropoda) (Stoddard 1931). Lehmann (1984) reported that peak insect consumption occurred during fall and winter in south Texas; termites (Isoptera) were most frequently eaten, followed by grasshoppers, spiders, beetles, and ants. Jackson (1969) cited grasshoppers as the most abundant insects found in quail crops from the Rolling Plains of northwest Texas; other common invertebrates were winged ants, beetles, true bugs, spiders, and various larvae. During a winter when there was a general scarcity of seeds, bobwhites from different pastures of a management area showed diets consisting largely of insects, 50% to 75% of which were stink bugs (Jackson 1969).

Diet in relation to age. Newly hatched chicks leave the nest within hours of hatching and must locate small, nutritious food items while searching alongside their parents. Their diet consists almost entirely of small

invertebrates for the first 2 weeks of life (Fig. 9) (Hurst 1972, Eubanks and Dimmick 1974). The proportion of plant material increases steadily for 8 to 10 weeks, at which time their diet becomes similar to that of adults.

Jackson et al. (1987) stated that chick invertebrate selection may be one of the least understood aspects of bobwhite biology. Although chick nutritional and energetic requirements for growth and survival are known, information about invertebrates consumed and their ability to meet nutritional requirements is limited (Hurst 1972). Jackson et al. (1987) examined invertebrate density and biomass, bobwhite chick invertebrate selection, and vegetative characteristics in old field, fertilized old field, and fertilized kobe lespedeza plots for two summers (1985 and 1986) in northern Mississippi. Bobwhite chicks of all ages preferred beetles, most of which were either ground beetles (Carabidae) or leaf beetles (Chrysomelidae, primarily flea beetles) from 1 to 5 mm long. Coleoptera larvae and true bugs were also preferred insect foods. Total invertebrate density and biomass were not different among treatments, but beetle density and biomass were greatest in fertilized kobe lespedeza plots during the second summer (Jackson et al. 1987).

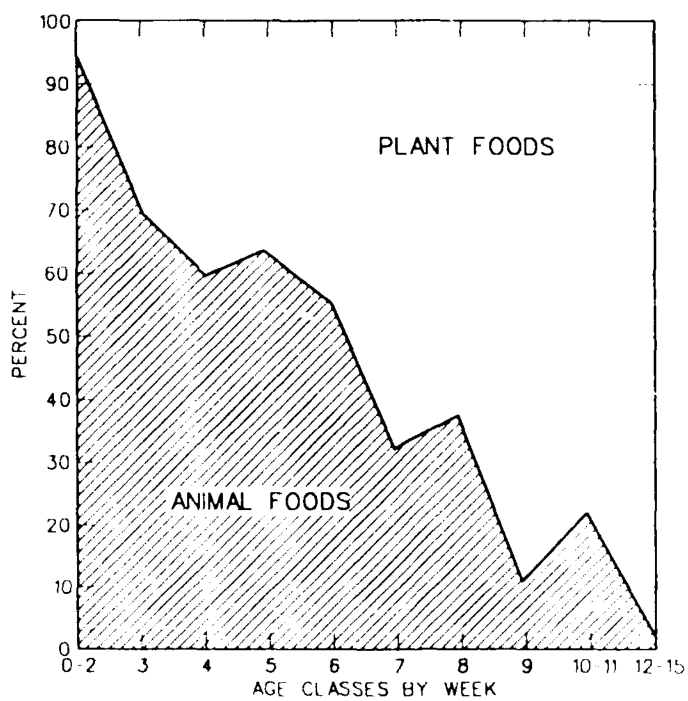

Figure 9. Dietary patterns of juvenile bobwhites in relation to age (Eubanks and Dimmick 1974)

Hurst (1972) also reported that beetles were the most important food of bobwhite chicks and determined that population densities and biomass of herbivorous insects were greater on burned versus unburned old field habitat. Koerth et al. (1986) examined bobwhite food habits on burned and unburned south Texas rangeland and found that chicks selected for grasshoppers on the burned areas, whereas no preference for any particular group of invertebrates was evident on unburned sites. One year after burning, grasshoppers and beetles dominated the insect portion of the diet and were selected in proportion to their availability. Spiders (consumed in proportion to their availability) and grasshoppers (eaten less than indicated by their availability) dominated the invertebrate diets on the unburned area.

Diet in relation to sex. The diet of both sexes is similar from autumn to early spring. Beginning in March, adult females increase their consumption of green leafy material such as clovers, lespedezas, and other early emerging herbaceous plants. They increase their consumption of invertebrates also. Cocks increase their intake of plant material at this time, but less so than hens (Eubanks and Dimmick 1975). This shift by females may reflect an increasing need for vitamin A and protein with the onset of egg laying, whereas males may benefit from a diet higher in energy.

Food-habitat relationship. The basic food resource of bobwhites is derived chiefly from habitats that have been recently disturbed. In agricultural areas, the disturbance occurs annually during tilling, planting, cultivating, and harvesting of the crops (Fig. 10). Crop seeds and associated weed seeds are easily located on the bare or nearly bare ground in agricultural fields and field borders. Pine plantations of the Coastal Plain are managed by periodic prescribed burning, which removes the accumulation of litter and encourages growth of wild legumes (Fig. 11). Depending upon site quality and other factors, such as the need to control hardwoods, burning may be accomplished at 1-, 2-, or 3-year intervals. This enhances the food supply and the opportunity for bobwhites to find seeds and insects. In western rangelands, moderate grazing, selective brush removal, disking, and burning encourage growth of good food plants and retard the development of plant communities unfavorable to bobwhites.

During some years in some environments, bobwhites obtain substantial nutrition from woodland mast crops, particularly acorns and dogwood seeds. Manipulation of hardwood forests is neither necessary nor desirable for the production of bobwhite foods.

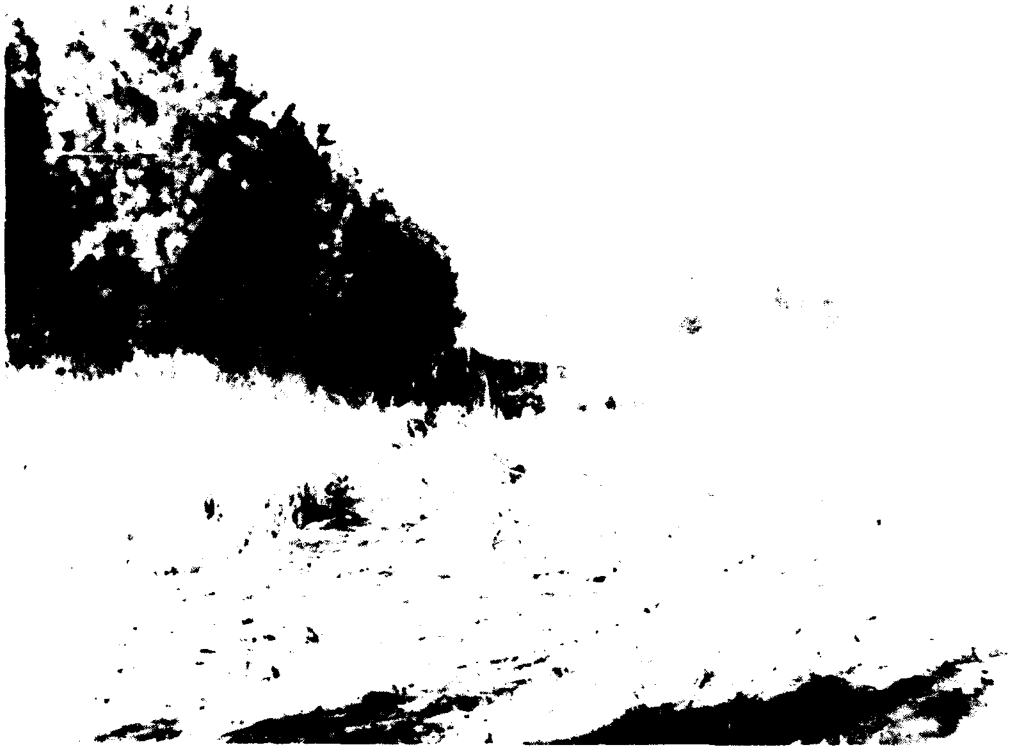

Figure 10. Characteristic feeding area for bobwhites in agricultural habitat

Cover

Two structurally distinct plant community types provide most of the bobwhite's cover requirements on a daily and annual basis (Fig. 12). Herbaceous growth with a variable mixture of grasses and forbs provides nesting cover, day and night roosting cover, and travel corridors. Woody communities, including brush, mature woods, and woody vines such as Japanese honeysuckle (*Lonicera japonica*) and trumpet creeper (*Campsis radicans*), serve as roosting cover, travel lanes, and protective cover from predators, hunters, and severe weather. Good bobwhite habitat has both herbaceous and woody community types in proximity to each other and to a reliable source of food. Bobwhites move freely among these plant communities, often selecting several different specific situations during a single day.

Protective cover. Protective cover shields birds from ice, snow, wind, hunters, and predators. Hardwood brush is an extremely important habitat component throughout the bobwhite's range, particularly where winter weather is severe. Bobwhites in Kansas establish winter covey headquarters (activity centers) in brushy and woody cover (Robinson 1957). In Wisconsin,

Figure 11. Characteristic feeding habitat in southern pine forests managed by prescribed burning

the amount of suitable hedgerow determines the habitat quality for bobwhites (Kabat and Thompson 1963, Dumke 1982), and in Missouri, fencerow cover strongly influences the carrying capacity of a site (Murray 1948). Roseberry and Klimstra (1984) emphasized the importance of woody or brushy areas for covey headquarters in southern Illinois and noted that Japanese honeysuckle was frequently an important understory component. Yoho and Dimmick (1972b) defined 10 activity centers used by coveys in Tennessee; nine of these were characterized by honeysuckle understory in a forested area adjacent to a grain or weed field.

In the coastal flatwoods, low, wet areas populated with hardwoods are interspersed among drier sites occupied by mature pine stands with herbaceous understory. These hardwood sites are often dense and provide adequate protective cover (Stoddard 1931). Shrub species are selected as loafing coverts in southern Texas based on their ability to protect birds from the adverse effects of heat, high winds, rain, and cold temperatures (Johnson and Guthery 1988). A high-quality headquarters area in Texas rangelands consists

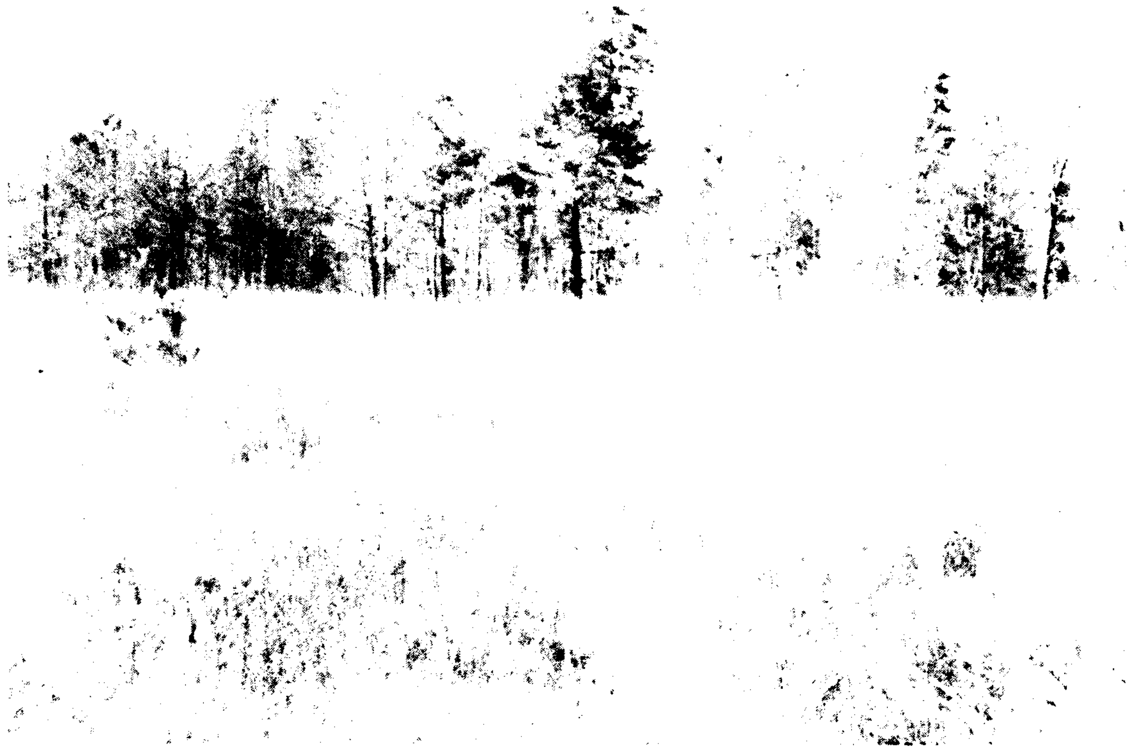

Figure 12. Plant community types that provide most of the bobwhite's daily and annual cover requirements: herbaceous nesting cover (foreground) and woody protective cover (background)

of a dense, thorny brush canopy at least 0.31 m (1 ft) above the ground (Lehmann 1984, Guthery 1986) (Fig. 13). In all cases, woody brush and/or vines are important because they provide overhead concealment and shelter, reduce predator ingress, and do not break down during winter.

Roosting cover. Bobwhite coveys roost on the ground in tight circles with sides touching and heads pointed outward. The space occupied by a covey of 12 birds is about the size of a large dinner plate. Night roosts are occupied from sundown to sunrise. Day roosting usually occurs from late morning to early afternoon, occupying the time between the 2 characteristic feeding periods of early morning and mid- to late-afternoon (Yoho and Dimmick 1972b). The same cover used for protection often serves well as roosting cover. In a sample of 107 roosts of radio-marked bobwhites in Tennessee, 63 were located in honeysuckle, and 12 were under low boughs of eastern redcedar (*Juniperus virginiana*) (Yoho and Dimmick 1972b). Herbaceous cover, such as broomsedge (*Andropogon virginicus*) and lespedeza, is commonly used in the Southeast. Quail characteristically selected broomsedge for roosting

Figure 13. Protective cover for bobwhites is provided by thorny brush in southwestern rangelands

in southern Illinois (Klimstra and Ziccardi 1963, Bartholomew 1967). However, during a lengthy period of heavy snow cover in that same region, Roseberry (1964) observed a shifting of roosting sites from open to woody cover, especially to clumps of Japanese honeysuckle.

Roosting cover is likely to be present in adequate amounts and properly distributed in habitats with sufficient protective and nesting cover. It need not be given specific management attention in otherwise good habitat.

Nesting cover. Bobwhites always construct their nests on the ground, and almost always choose a plant community dominated by perennial grasses for the nest site (Fig. 14). On the Rio Grande Plain of south Texas, 358 of 391 nests were sheltered by sturdy perennial grasses (Lehmann 1984). In southern Illinois, the vegetation types most responsible for protective cover at 412 nests were broomsedge (25.5%), cheatgrasses (*Bromus* spp.) (16.3%), bluegrasses (*Poa* spp.) (13.3%), and briars (*Rubus* spp.) (11.2%) (Klimstra and Roseberry 1975). Broomsedge provided cover for 56% of 602 nests examined in north Florida; 16% were in woodland, 15% in fallow fields, 4% in cultivated fields, and 10% unclassified (Stoddard 1931). Broomsedge was the dominant

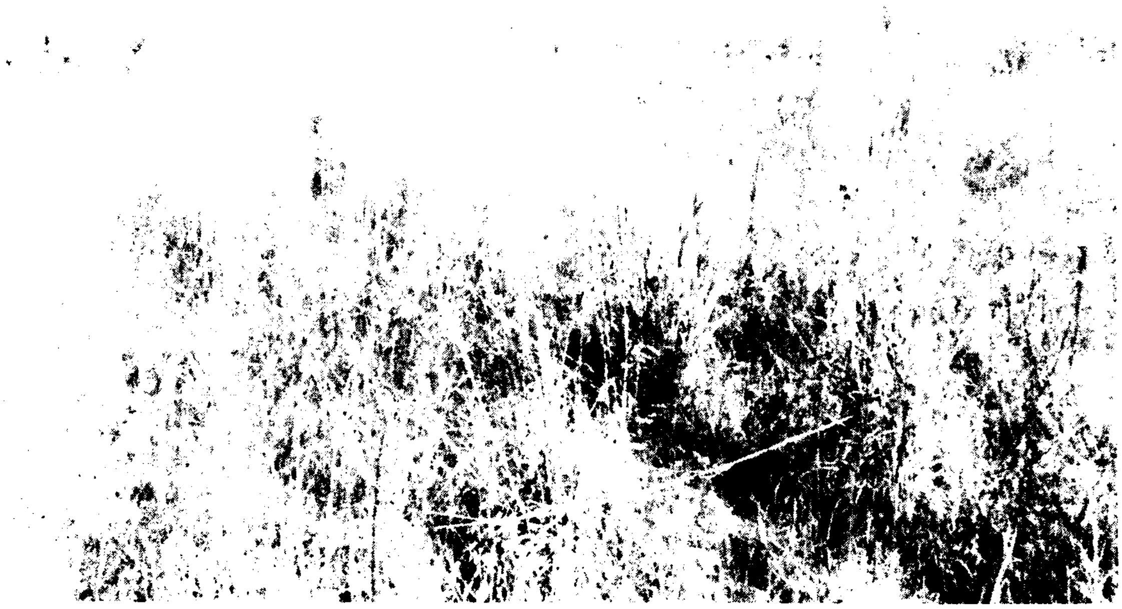

Figure 14. Excellent nesting cover composed of perennial grasses

plant used for nesting by Tennessee bobwhites (Fig. 15) (Dimmick 1968), but several plant species were utilized, including grasses killed by herbicides in a no-till soybean field (Minser and Dimmick 1988).

Across its wide range, the bobwhite finds good nesting habitat in a variety of situations. Idle fields dominated by broomsedge consistently provide excellent nesting habitat, but only when free from invasion by tall fescue (*Festuca arundenacea*), bermudagrass (*Cynodon dactylon*), or similar ground-cluttering grass species. The clumping nature of broomsedge, with abundant nearly bare ground between clumps, offers excellent concealment of the nest and travel lanes for the birds. Fair to excellent habitat is provided by grassy roadsides and fencerows, moderately grazed grass or mixed grass-legume pastures, 1- to 2-year-old fallow fields, and some no-till crop fields. Excellent nesting areas in the coastal plain consist of mature, lightly to moderately stocked pine forests with their herbaceous layer maintained by fire. Hardwood or pine forests with dense canopies shading out a grassy understory are of no value as nesting habitat.

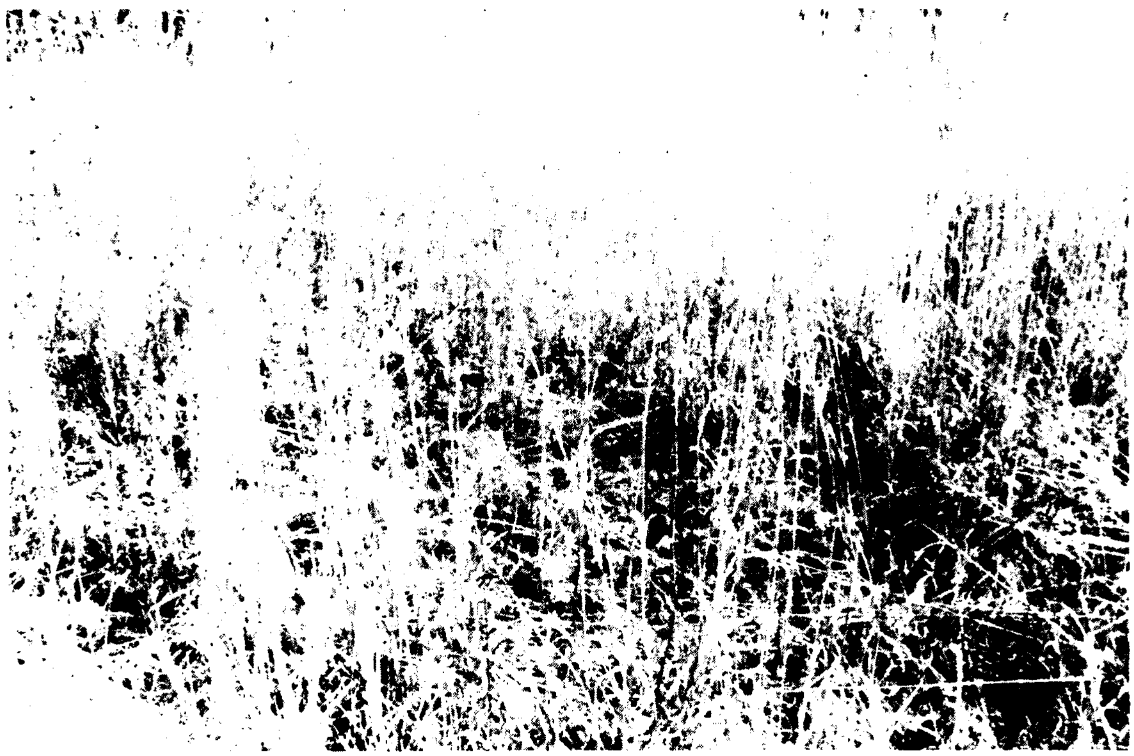

Figure 15. Broomsedge nesting cover managed by controlled burning; note clumps of grass interspersed with openings at ground level

In southwestern rangeland, low-growing thorny shrubs serve as grazing exclosures, and bobwhites often nest in ungrazed bunchgrass beneath and among these shrubs (Guthery 1986, Kuvlesky 1990). A variety of habitat types, their physical and vegetative components, and breeding use by bobwhites were examined by Reid et al. (1977) for 10 ecological regions in Texas. Bobwhite density was correlated with habitat parameters that provided adequate food, cover, nest sites, and song posts; mesquite appeared to be important nesting cover for nesting bobwhites in 7 of the regions.

Size of the unit of nesting habitat is of little consequence to its acceptability by quail. Narrow strips of roadside cover, broad expanses of old fields or pasture, and small idle corners of crop fields are all acceptable. Suitability of the environment for nesting bobwhites is determined by the quality and total amount of nesting habitat in relation to the nesting population, rather than the size or shape of individual units.

Brood-rearing habitat. The major considerations for brood habitat are the abundance and availability of insects (Hurst 1972). Lush, succulent

vegetation provides a good food base for insects and is an important component of brood habitat (Fig. 16). Forbs were an essential component of brood-rearing habitat in south Texas (Kuvlesky 1990). Agricultural crops not heavily treated with insecticides (e.g., soybeans) and native vegetation developing on sites disturbed by fire or disking are good brood habitat. In addition to their healthy insect communities, these vegetation types are relatively litter free at the ground surface, which enhances the freedom of movement of the small chicks and provides some measure of protective cover. Strips of clover (*Trifolium* spp.) planted along edges of woods, roadsides, and brushy fencerows serve as good areas for raising broods; moderately grazed pastures are also used. Patches or strips of bare ground will facilitate the movement of chicks in brood-rearing areas (Guthery 1986, Wilkins 1987, Kuvlesky 1990).

The special needs and fragile constitution of bobwhite chicks place a premium on good brood habitat. However, this aspect is often overlooked when planning and conducting bobwhite habitat improvements.

Figure 16. Brood habitat in an agricultural area, showing feeding areas with insect-producing foliage (soybeans) and bare ground adjacent to escape cover

Habitat Evaluation

Several methods are available for evaluating habitat quality for the bobwhite. A Habitat Suitability Index (HSI) model has been developed for the US Fish and Wildlife Service Habitat Evaluation Procedures (Schroeder 1985). The model was designed to evaluate the year-round habitat needs of bobwhites and theoretically can be applied to populations throughout the species' range. Application of the model requires the collection of data on 10 habitat variables used to determine a winter food index and a cover index. Life requisite values are then calculated for winter food, nesting, and cover for each major cover type (e.g., forest, shrubland, cropland) in a specific study area. These values are weighted based on the relative percent of each cover type and the degree of interspersion, and the weighted values are summed. A Suitability Index value is then calculated for each weighted life requisite by using the indices for 4 additional variables that represent habitat composition and interspersion.

Other habitat models have been developed regionally for bobwhites. An index based on the interspersion of vegetative types was designed to evaluate bobwhite habitat in Nebraska (Baxter and Wolfe 1972); according to Schroeder (1985), this model was found to produce an output that correlated well with bobwhite numbers. Urich et al. (1983) developed a habitat model for the bobwhite in Missouri. The model is used to assess various habitat characteristics in bottomland hardwoods, upland hardwoods, old fields, cropland, and pasture and hay land and results in a numerical output for each cover type; however, it does not have the capability of providing a single value for a composite of several different cover types (Schroeder 1985).

Existing habitat-based models would likely need to be tested and verified before application on a specific study area. In most cases, variables used in the HSI model would need to be reduced to a workable number of those considered most representative of habitat quality for cover types within a region. The manager should understand that habitat-based methods provide a numerical value that shows the potential for a site to support a species; however, results of the model should never be applied to indicate a population estimate.

MANAGEMENT

There are 2 principal elements to managing bobwhites: population management and habitat management. To manage bobwhites properly, the biologist needs to first determine the status of the population and the condition of the habitat on the area of concern. Once these have been determined, habitat inprovements can be implemented as needed to achieve the desired density of bobwhites that is reasonable for the area. The harvest can then be regulated to ensure continuation of the desired density compatible with the manager's concept of high-quality hunting.

Population Surveys

Determining the number of bobwhites on an area to be managed is an important first step for delineating habitat needs and evaluating the success of habitat management practices. On a larger scale, tracking population trends may provide sufficient information for monitoring the effects of major land use changes and for refining statewide hunting regulations. The bobwhite's nonmigratory behavior, small home range, social behavior of clustering in coveys, and tendency to flush at close range when disturbed have enabled researchers to develop several methods for estimating population density. The territorial whistling of males during summer is used for establishing annual trends, for comparing bobwhite densities among different land use systems, and for forecasting fall populations. Rarely has any technique been adequately tested against bobwhite populations of known density to establish its precision and/or accuracy. Several methods used to estimate bobwhite populations are described below.

Walk census. The walk census is a direct count conducted most efficiently by having teams of 5 to 8 persons walk abreast and attempt to flush all coveys present in an area; there should be a spacing of about 20 steps (20 m or yards) between each crew member. The team leader walks at the center of the census line and traverses a straight path along a predetermined compass bearing. The team starts at one boundary of the area to be censused and walks at a moderate pace (about 1 mile/hour depending upon the density of the habitat) from border to border until the entire area has been covered. Coveys are located on a map, their numbers are recorded, and cover types and other relevant data are noted. Klimstra and Roseberry (1984) and Guthery (1986) utilized a walk census in southern Illinois and Texas, respectively, but their

spacing, terminology, and interpretation of results were somewhat different. The walk census provides an acceptably precise count, but the number of coveys located consistently averages about 50 percent of the actual number of coveys on the area (Dimmick et al. 1982).

A team consisting of 1 experienced leader and 4 inexperienced helpers can census about 200 ha (500 acres) in 7 to 10 hours. All cover types are traversed with the same spacing, though large expanses of plowed or disked areas may be ignored with no sacrifice in precision. The census may continue from sunrise to just before sunset. It should not be conducted during moderate to heavy rainfall or snowfall, but moderate wind velocity or cold temperature are acceptable weather conditions. The walk census is appropriate to use during late fall, winter, and early spring. However, it cannot be used successfully when the vegetation is lush and green.

<u>Strip transect</u>. The strip transect is a variation of a walk census in which only a portion of an area is traversed and the number of animals observed is expanded to account for the percent of area not censused. The width of the strip and proportion censused varies according to the decision of the census worker. Dimmick et al. (1982) reported that an estimate derived from a 20% strip census was poorly correlated with estimates obtained by either a complete walk census or a Lincoln Index. However, the walk census and Lincoln Index estimates were highly correlated.

<u>Line transect</u>. In line transect (LT) sampling, straight lines of predetermined distances are traversed on foot or in vehicles (Guthery 1988). When an animal or group of animals is observed, the number and right-angle distance from the transect line to the point of flush or observation are recorded. LT theory is based on a detection curve that describes the probability of detecting groups (coveys) or individuals. Guthery (1988) considered line transects a reliable method for estimating density of northern bobwhites on Texas rangeland. Kuvlesky et al. (1989) obtained LT data from a bobwhite population of known density in south Texas brushlands and reported that line transects may be unsuitable for estimating bobwhite density in areas with low populations.

Guthery (1988) suggested that the greatest shortcoming of LT sampling was the large sampling effort (total distance walked) required to obtain acceptable levels of precision in Texas brushland. Guthery allocated about 4 person-days to walk line transects that would sample about 15% to 30% of areas 250 to 500 ha (617.5 to 1235 acres) in size. By comparison, a team of

5 individuals can conduct a 100% walk census of a 200 ha (494-acre) area in 1 to 2 calendar days (5 to 10 person-days).

Lincoln Index. The Lincoln Index (LI) estimator applied to bobwhites provides a precise and accurate estimate of the presample population using a 2-sample set of data (Dimmick et al. 1982). The first sample consists of bobwhites captured in grain-baited live traps, leg-banded with numbered aluminum leg bands, and released at the point of capture. The second sample is obtained by shooting immediately following the conclusion of banding.

Trapping the first sample requires about 15 to 20 calendar days. Traps are placed in appropriate cover (brushy edges and woodlands), using about 1 trap per 2 ha (2.94 acres). Trapping is concluded when the percentage of unmarked birds captured is low (usually 5% or less). Systematic intensive shooting commences 2 to 3 days after the end of trapping and continues until approximately 50% of the banded birds are recovered. The population existing on the area prior to shooting (N) is estimated as follows:

$$N = \frac{Mn}{m}$$

where

M = number of bobwhites banded and released

n = total number shot, including banded and unbanded birds

m = number of banded birds recovered by shooting

Davis and Winstead (1980) provided a method for determining 95% confidence limits for the LI estimate of population size.

The LI provides the most accurate estimation of bobwhite population size. It also permits researchers to determine sex and age ratios, movement data, and health and condition of the birds. Its disadvantages include a large expenditure of effort (e.g., 80 to 100 person-days for one estimate on 200 ha [494 acres]) and significant mortality (25% to 30%) imposed by shooting and trap-related deaths. The LI was found to underestimate the known density of a bobwhite population in south Texas (Kuvlesky et al. 1989).

Call count. The call count (also referred to as the whistle count or whistling cock count) is derived by counting the number of whistling male bobwhites heard along a predetermined route with a fixed number of stations for listening. In moderately dense to dense populations it is difficult to identify individual birds, and in those circumstances the number of whistles

per station provides the data base. To conduct the count, the observer typically drives a route with 10 or more designated stations; at each station he stands outside the vehicle, listens for 3 to 5 minutes, and counts all birds or all whistles. These data are then used to determine the mean number of birds (or whistles) per station (Bennett 1951; Rosene 1957, 1969; Wakeley et al. 1990). This index has been used to compare breeding populations among areas and/or years; it has also been used to forecast fall populations and project hunting success, but current evidence indicates that this is not a valid use for the whistle count. Reid et al. (1977, 1979) reported that habitat types and their structural features were correlated with bobwhite whistle counts in Texas.

The call count is limited to use during the peak of breeding activity, which may vary among years and regions. Its use is also restricted to early morning hours, when whistling activity is greatest and most consistent (1/2 hour before sunrise to about 1 to 2 hours after sunrise). Results are strongly influenced by weather conditions and observer detection skills.

Implicit in using this index as a population estimator are the assumptions that the number of calling birds and/or the number of whistles are consistently correlated with the number of bobwhites present during the breeding season. It is also assumed that breeding success is somehow related to calling activity. Neither of these important assumptions have been verified, and both may be invalid. Norton et al. (1961) noted that summer whistling was not proven to have a substantial statistical relationship with autumn populations, nor was it sufficiently reliable for setting harvest regulations.

The call count was tested for bobwhites on a research area in western Tennessee for which good estimates of the December population density were available for an 8-year period. Correlation between total whistles/4-minute station during July and the subsequent December populations was close to zero. The lowest December population (908 bobwhites) and the highest (2210) were preceded by nearly identical call counts of 38.0 and 37.8 whistles per station (R. W. Dimmick, unpubl. data).

Advantages of the call count include its simplicity for use by unskilled workers and the relatively small amount of effort required to generate a large amount of data. Its disadvantages include the potential for serious observer and weather biases and its generally poor performance as a predictor.

Recommendations. The census method(s) selected will be governed by constraints of time and cost, objectives of the census, the desired degrees of

accuracy and precision, and to a lesser extent the nature of the habitat. The greatest accuracy and precision will be achieved with the capture-recover procedure using the Lincoln Index, but it is also the most costly and time-consuming. The walk census provides acceptable precision and achieves acceptable accuracy when adjusted as described by Dimmick et al. (1982). The walk census works best when applied to square or rectangular areas ≥200 ha (500 acres). The line transect may provide acceptable levels of precision in habitat characterized by relatively uniform sparse cover, such as semi-arid grassland or brushland. It may also be fairly accurate, depending on the estimator used, in high-density populations (Kuvlesky et al. 1989). The strip transect and call count index are not recommended by this author as valid population estimators.

Defining Population Objectives

The usual management goal for bobwhites is to maintain populations at densities suitable for recreational hunting. Bobwhites can be managed successfully on areas as small as 200 ha (500 acres), and they respond quickly to good management. Where bobwhite management is the sole or primary land use, densities of 2 to 3.6 birds/ha (1 to 1.5/acre) can be maintained. Within this range of densities, annual harvests of 200 to 300+ birds per 200 ha are safe and reasonable.

Most public areas are managed for multiple uses, whereas private farmlands and forestlands are usually managed for profit. Accommodating these alternative uses typically lowers expectations for bobwhite densities because the options for management practices are fewer. Fall bobwhite densities as low as 1 bird/1 to 2 ha (2.5 to 5 acres) may provide acceptable recreational hunting on such areas.

To arrive at a reasonable population objective, the manager should accomplish the following steps:

(1) Develop a detailed map of the management area, to include the identification of cropland and crops usually planted, forestland by forest types, rangeland and brush types, idle land in early to old field succession, and pasturelands.

(2) Census the area in November or December after crops have been harvested or before the hunting season begins. If the area is larger than about 400 ha (about 1000 acres), censusing subunits of 200 ha stratified by land use type will be sufficient.

(3) Delineate areas insufficiently populated with birds. Assess the habitat shortcomings in these areas, and evaluate the cost and

probability of success of management practices to improve or correct these deficiencies.

(4) Set a reasonable time table for achieving the population objective. Where winter food is deficient in agricultural lands, the correction may be accomplished in 1 summer, and the population should respond measurably in 2 years. Where woody cover is lacking, the time table may require 4 years or more for a population increase. If nesting cover is deficient in quantity or distribution, correcting the deficiency may require 2 to 4 years, and a 1- to 2-year lag time should be allowed for a population response.

Habitat Management

Habitat management activities range from low-level maintenance practices designed to forestall undesirable changes in good habitat to intensive and extensive land use changes that will correct major deficiencies in poor habitat. The most effective strategy for upgrading habitat quality is to determine the limiting factors within specific units of a management area and to remove or reduce those limitations with an appropriate habitat alteration.

Habitat factors that commonly limit bobwhites throughout their range include

(1) Amount, quality, and/or distribution of winter food.

(2) Availability of winter protective cover.

(3) Quality and distribution of nesting cover.

(4) Availability of insect food in suitable feeding areas for young quail.

(5) Sufficient loafing areas and travel lanes for winter coveys.

All of these elements may be provided in a single, well-managed plant community in some land use systems (e.g., Coastal Plain forests of mature pines and in southwestern rangeland). However, 3 or more distinct plant communities may be required in other systems, such as midwestern or mid-South agricultural lands.

Winter food. The winter food of bobwhites is essentially seeds. Although hundreds of species are eaten, only 10 to 20 species comprise the bulk of the diet in any localized area. Food is scarcest in late winter (February-March) over most of the bobwhite's range. However, in semi-arid parts of Texas and Oklahoma, the critical season may vary among years, as it is influenced by seasonal rainfall (Jackson 1969, Lehmann 1984).

The winter food supply can be enhanced by several approaches in agricultural lands. The simplest is to delay plowing or disking of crop residues until just before planting the next year's crop (Figs. 17 and 18). Practicing

Figure 17. Fall plowing covers crop residues that are important winter food for bobwhites

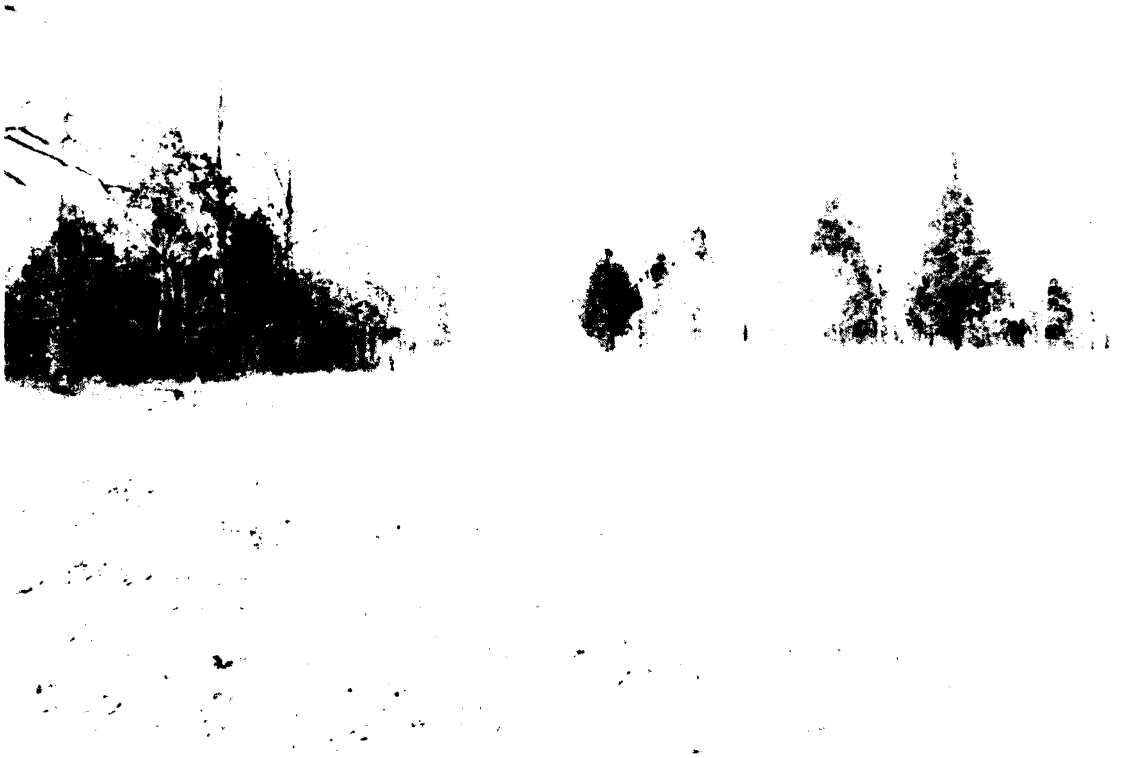

Figure 18. Delaying tillage until spring protects the winter food supply

no-till agriculture is also effective and highly desirable (Fig. 19) (Dimmick and Minser 1988). Retaining small patches (0.03 to 0.10 ha [0.06 to 0.25 acre]) of unharvested crops strategically located near protective cover is an excellent practice. Maintaining a border of reseeding annuals, such as Korean or common lespedeza, around agricultural fields provides highly nutritious seeds that last well into the spring, and also provides green leafy material needed by adult females during spring for egg production. Planting annual food plots is high-intensity management, but can be effective. Soybeans, corn, sorghum, and sunflowers all provide seeds that remain available into late winter if managed properly.

Wild legumes and other early succession plants are important winter foods in Coastal Plain pine forests, where many of these species are maintained by periodic prescribed burns. Controlled burning on a 1- to 3-year cycle, usually done in January or February, reduces the invasion of hardwoods and stimulates the production of quail foods, including wild lespedezas. Several other habitat management practices will enhance bobwhite populations in this favorable environment. Creating and maintaining up to 10% of the area

Figure 19. Practicing no-till agriculture protects the winter food supply and also increases winter cover and nesting habitat

in agricultural openings should increase bobwhite population density (Mueller 1990). These openings may be up to about 4 ha (10 acres) in size and should be scattered throughout the management area as much as possible. Fire lanes, utility lines, and log loading areas may be incorporated into the system of openings.

Hard mast, particularly acorns, and soft mast, such as flowering dogwood and black cherry (*Prunus serotina*), are important bobwhite foods. Existing mast-producing trees should be preserved within the pine forest by protecting them from fire. A density of 1 producing oak tree per 0.8 ha (2 acres) is sufficient. Well-distributed clumps or strips of shrub lespedezas (*L. bicolor* and *L. thunbergii*) work well as understory plants in mature stands of southern pines. Disking in springtime without planting will frequently stimulate the growth of valuable winter foods (e.g., common ragweed) and will inhibit the growth of undesirable sod-forming grasses.

On Texas rangelands, Guthery (1986) recommended disking anytime during the winter or burning during December to stimulate the production of wild food plants. Grazing at appropriate stocking rates can also be used to enhance food production in rangeland systems (Jackson 1969, Guthery 1986, Wilkins 1987, Schulz and Guthery 1988). Annual food plots may be useful in landscapes lacking natural foods. Various combinations of annual lespedezas, sunflowers, partridge pea, and grain sorghums may be selected. Where food plots are managed for quail on rangelands, it is important to fence the plot to exclude livestock until seedheads are mature; cattle should then be let in to knock the seedheads down, making the grain accessible to quail (Jackson 1969, Lehmann 1984, Guthery 1986). Annual rainfall and cultural requirements should be considered when selecting specific varieties for food plots.

<u>Protective cover</u>. Bobwhites typically seek protection from adverse weather or escape from predators and hunters in the relative safety of dense woody or viny coverts. In northern regions, cover shields the birds from snow and ice and often provides access to emergency foods, such as honeysuckle, when crusted snow or ice have covered their normal foods. Brushy cover and brushpiles provide shady resting areas during intense summer heat in the hot, semi-arid rangelands of the Southwest. In more moderate climates, adequate escape cover may be provided by woodland understories and edges of honeysuckle, small patches of young pines, plum (*Prunus* spp.) thickets along fencerows and field borders, and patches or strips of shrub lespedezas. These sites are also relatively secure areas for loafing, roosting, and traveling.

The common characteristic of protective cover is its sturdiness and ability to withstand the deteriorating effects of snow, ice, and freezing temperature. On a geographical gradient, sturdy woody cover is most critical in the snow-cold regions and least critical in the balmy climate of the Coastal Plain pine woods. It is also critical in southern Texas, where brush coverts mitigate the effects of very hot summer temperatures.

Managing protective cover can be done effectively using a 3-step procedure. Step 1 entails making an inventory of existing suitable cover units by marking their locations on maps or aerial photos. Acceptable cover units include woody fencerows or field borders at least 7 m (21 ft) wide, forest edges with at least 3 to 4 m (9 to 12 ft) of viny or brushy understory, and isolated patches of woody cover in blocks of at least 0.1 ha (0.25 acre).

Step 2 consists of protecting and/or maintaining existing cover units. Mechanical removal of brush and excessive grazing pressure eliminate or lower the value of protective cover. These activities are commonly associated with intensive farming and can subtly or dramatically lower the carrying capacity of the habitat for bobwhites. Controlled burning in Coastal Plain pinelands may eliminate patches of upland hardwoods while leaving riparian hardwoods on sites too moist for regular burning. These wet hardwood sites may be frequented by bobwhite predators, thus reducing their value as protective cover. To avoid excessive use of moist sites by bobwhites, well-dispersed units of upland hardwoods should be protected from annual burning. These cover units should be about 0.8 to 2 ha (2 to 5 acres) in size, and should be manipulated by burning or bushhogging only as often as needed to prevent their maturing to stands with open understories (Mueller 1990). In semi-arid rangelands of Texas, small patches of brush are essential in grazed pastures. Small, well-dispersed units of brush constituting no more than 15% of the total area are necessary to maintain bobwhites (Guthery 1986).

Step 3 is accomplished by establishing new units of protective cover where it is lacking. The following practices may be effective:

(1) Planting woody shrubs or rapid-growing trees. Bicolor lespedeza seeded in strips 4 to 5 m (12 to 15 ft) wide will produce travel lanes and moderate protection in about 2 years. Autumn olive (*Elaeagnus umbellata*) planted as seedlings (sprigs) will produce suitable cover in 3 to 5 years (Fig. 20); two rows spaced 2 to 3 m (6 to 9 ft) apart should grow into an effective cover strip about 5 m (15 ft) wide. Strips of pine seedlings planted in 4 rows with spacings of approximately 2+ m (6 to 7 ft) between rows will produce a cover strip 8 to 10 m (24 to 30 ft) wide in about 5 to 7 years depending on site quality (Fig. 21). Loblolly pine (*P. taeda*)

Figure 20. Autumn olive planted to provide bobwhite protective cover and travel lanes

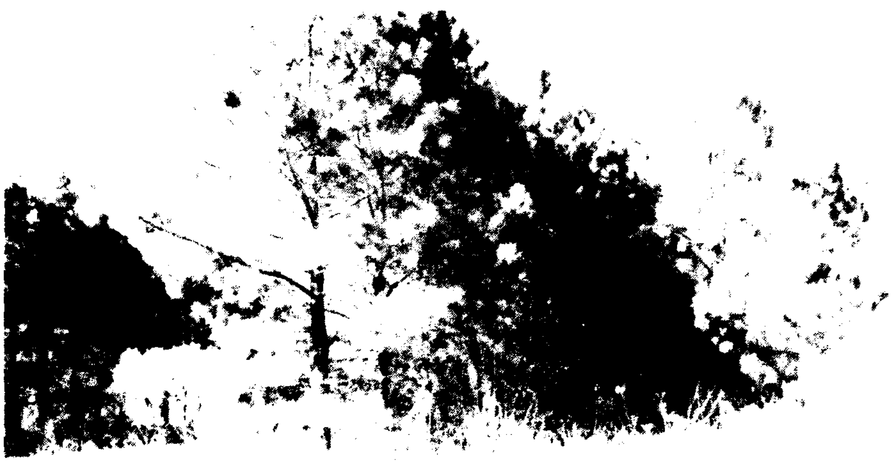

Figure 21. Loblolly pine produces excellent cover in 5 to 7 years

is a preferred species because it can be managed successfully where prescribed fire is incorporated in the management plan. White pine (*P. strobus*) may grow better in colder areas but is more easily damaged by fire.

(2) Half-cutting trees to produce living brushpiles. In narrow fencerows with a single line of trees, half-cutting some of the trees and dropping them perpendicular to the fencerow can provide cover quickly (Jackson 1969, Lehmann 1984, Guthery 1986, Steele and Martin 1986). This practice will also likely reduce the tendency to farm all the way up to the fenceline. Natural succession will soon extend the width of the fencerow and enhance its value for protective cover.

(3) Construction of brush piles. Although living brush is preferable, artificial brush piles can be constructed to provide immediate shelter for bobwhites where natural cover is limited (Guthery 1980, Dumke 1982, Webb and Guthery 1982, Lehmann 1984, Martin and Steele 1986). Constructed brush piles are most appropriate for open semi-arid range and agricultural land in the Southwest and Midwest; they have limited application in the East, where stands of shrubby vegetation can be established within a short period of time. Although an extensive brush pile project can be costly in terms of labor requirements, brush piles constructed as a by-product of land-clearing operations can result in inexpensive short-term habitat improvements. Artificial brush piles can also provide homes for a variety of species other than bobwhites, thus extending their overall benefits.

Nesting cover. Bobwhites nest on the ground in herbaceous cover dominated by grasses. Widely used habitats include old fields dominated by broomsedge, grass-forb understories of open-canopied mature southern pine forests, pastures with clumpy grasses, and roadsides and fencerows with patches of bluegrass (*Poa* spp.) and cheatgrasses (*Bromus* spp.). Certain types of no-till cropfields (e.g., soybeans in wheat stubble) are utilized to some extent (Fig. 22) (Minser and Dimmick 1988).

Nesting cover is managed to retain a domination of grasses, remove excessive accumulations of duff and dead vegetation from the ground, and preserve some areas with the previous year's growth for material to construct nests. Where nesting habitat is adequate, it can be maintained in suitable condition by periodic prescribed fire. Maintenance burning should be accomplished in mid to late winter. Depending upon site quality, burning may be done at 1-, 2-, or 3-year intervals. A patchy burn, with irregular fire intensity, is desirable. This can be achieved when the abundance of fuel on the ground and the moisture content of the fuel are unevenly distributed. Areas with uniformly dense fuel may need to be burned in alternately arranged patches at staggered 2- or 3-year intervals. This will help ensure that some

Figure 22. Soybeans planted without tillage in winter wheat stubble provide acceptable nesting cover for bobwhites (arrow points to the nest)

areas with dead grass material are available for constructing nests early in the season (Dimmick 1971). The majority of prescribed fires in south Texas produce a patchy, incomplete burn, which results in an interspersion of habitats. The burned areas are characterized by younger vegetation, less litter, and more bare ground (better nesting cover and brood habitat), and the unburned areas support mature brush and rank grass thickets, which serve as escape cover (Wilson and Crawford 1979, Lehmann 1984, Scifres 1987).

Some potential nesting areas may have advanced in succession to the point that woody shrubs and trees are overabundant. Returning these areas to high-quality nesting habitat can be done by summer burns; these burns may be accompanied by the spot application of herbicides, if necessary. A cautionary note regarding the use of fire is in order. When done by skilled practitioners, prescribed burns are safe, economical, and effective. Fire is dangerous when used by untrained persons and should not be employed without close supervision by trained technicians. Agency and local regulations may require that the state forester, pollution control board, and other appropriate offices be notified when planning a burn.

The effects of grazing systems on nesting habitat have been discussed in several studies. Most studies in southwestern rangelands have determined that grazing pressure associated with short-duration systems appeared to favor quail populations and their key habitat features (Campbell-Kissock et al. 1984, Wilkins 1987, Schulz and Guthery 1988). However, Baker and Guthery (1990) reported that the response of bobwhites to grazing intensity was highly variable on a study area in southern Texas. Comparisons of the effects of short-duration and continuous grazing on bobwhite nests were discussed in Koerth et al. (1983) and Bareiss et al. (1986). Campbell-Kissock et al. (1984) indicated that short-duration systems appeared to provide better nesting and protective cover during drought years than continuous grazing. On southwestern rangelands, precipitation is an important variable in determining bobwhite habitat conditions within grazing systems.

Plant communities suitable for nesting are usually available in mature southern pine forests and in western rangelands. However, such communities may be absent or in short supply in agricultural land use systems. This circumstance occurs where all fields are planted to rowcrops, fencerows are devoid of suitable grassy areas, and there are no grassy borders between woodlands and fields. Creating new nesting habitat may require removing some land from cultivation. Widened fencerows, irregular field corners, and sloping areas within fields known to be low in productivity may be withdrawn from production or disturbance. Natural invasion of native grasses and forbs or seeded warm-season grasses may create suitable nest habitat in 2 to 4 years. Once established, these areas can be maintained by periodic prescribed burns. Areas withdrawn from agricultural use should be free of stands of tall fescue, bermuda grass, and sericea lespedeza (*L. cuneata*), as these plants eliminate or greatly lower the quality of nesting habitat.

The use of no-till agriculture has been shown to provide nesting areas for bobwhites (Minser and Dimmick 1988). No-till soybeans planted in wheat stubble were used about equally with fencerow nest cover on a western Tennessee farm. There was no measurable effect of herbicides on the hatching rate of nests in the crop field compared with nests in idle lands with no herbicidal treatments.

Brood habitat. Good brood habitat consists of sites that provide an abundant supply of small invertebrates, sufficient vegetative cover to shield chicks from predators, and vegetation density sparse enough at ground level to permit easy movement of very young chicks. The major considerations for brood

habitat are the abundance and availability of insects (Hurst 1972, Jackson et al. 1987).

Some management practices that enhance winter food production and nesting habitat also enhance brood habitat. Annual food plots, controlled burns, and disking increase the vegetation preferred by insects and increase their availability to chicks. Commercial soybean and milo fields provide most of the elements of good brood habitat, and they are heavily used by bobwhite broods. Planting strips of clover along the edge of travel lanes such as field roads, crop field borders, and woods edges will provide good-quality habitat where it is otherwise deficient.

Roosting and loafing habitat. Bobwhites spend portions of each day sleeping, resting, grooming, and traveling in search of food, shelter, mates, and companions. Many types of habitat elements are used for these activities. Night and day roosts may be in grassy cover, dense patches of honeysuckle, small clumps of brush, or open woodlands (Fig. 23). Grooming and dusting is done on dirt roads, in food plots, and along edges of cultivated fields. Bobwhites travel along field edges and fencerows, and wander through expanses

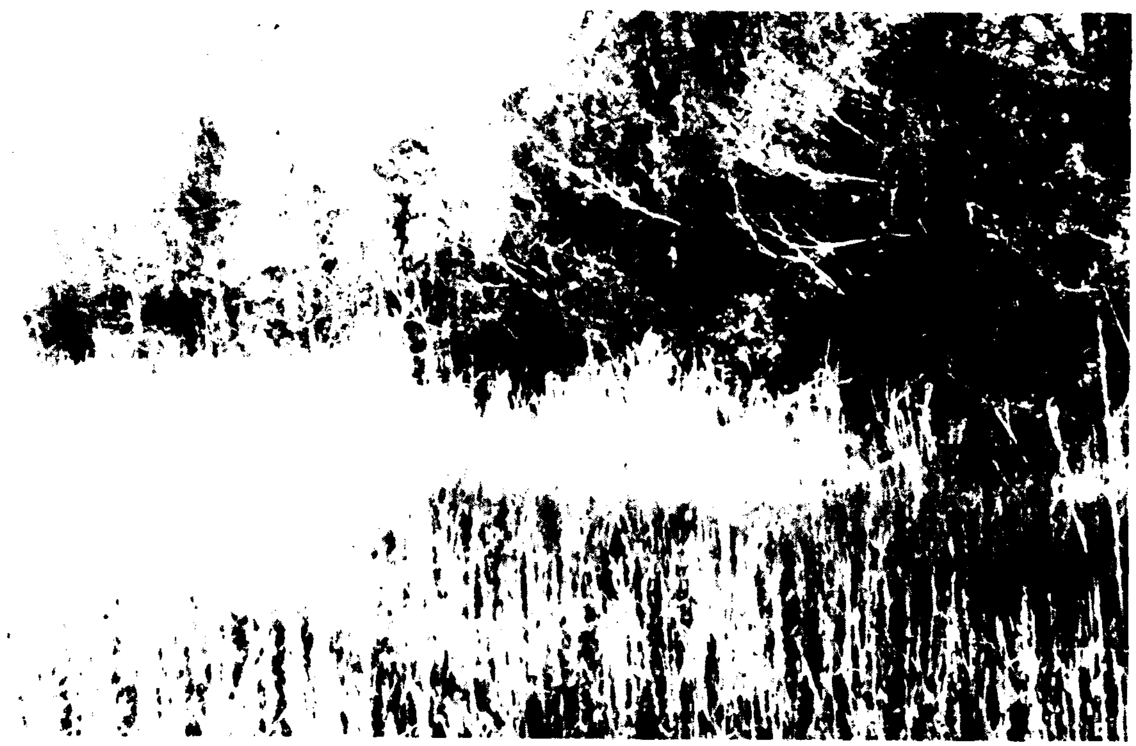

Figure 23. Bobwhites use a variety of cover types for night roosts and daytime loafing areas, including grass, brush, and woods

of broomsedge fields and woods. Habitat management practices that provide for all their other needs will also be suitable for these important activities.

Integration of habitat resources. Bobwhites are quite sedentary; thus, the spatial relationship among important habitat elements is a major determinant of habitat quality for local populations. Birds usually walk from place to place rather than fly; however they may make short flights across risky territory or to escape harassment. The highest quality habitats have the various plant community types needed for the bobwhite's daily requirements located close together.

In the mixed loblolly-longleaf pine (*P. palustris*) forests of the Coastal Plain, most of the bobwhite's needs are met in the diverse forb-grass understory. Regular use of prescribed fire maintains the appropriate structure and biological diversity that makes this plant community one of the most productive in the world for bobwhites. Adding annual or perennial food plots to this habitat may increase or stabilize carrying capacity but is usually not necessary.

Similarly, biological and structural diversity can be achieved within the extensive grazing lands of the Southwest. Pasture land suitable for bobwhites includes a mixture of grasses, forbs, and brush. A relatively uniform distribution of clumps of brush not exceeding 15% of the total area is ideal (Guthery 1986) (Fig. 24). Maintaining the correct species composition of forbs and grasses is accomplished by prescribed fire and carefully regulated livestock grazing. The abundance and distribution of brush can be regulated by mechanical means, with the use of herbicides, or by prescribed fire (Lehmann 1984, Guthery 1986). Food plots will enhance carrying capacity where native wild foods are insufficient.

The interspersion of habitat components was found to influence bobwhite habitat selection on the Rio Grande Plains of south Texas (Kuvlesky 1990). In this study, habitat was evaluated on both fine and broad scales of resolution at quail telemetry locations and at randomly selected sites that represented available habitat. On both scales of resolution, bobwhites selected habitats with a higher degree of habitat-component interspersion (indicating greater patchiness) than was generally available on the study area, and this tendency increased as environmental conditions became drier. Forbs appeared to be the most important fine-scale habitat component within the interspersion matrix, as forb patch-to-patch distance was the only variable that was consistently important each season; grass, shrubs, and bare ground were also important

Figure 24. Aerial view of mixed brush and grassland pasture used by bobwhites in southern Texas

habitat components. Agricultural management practices that reverse plant succession were recommended as techniques to improve habitat-component interspersion on brushland sites (Kuvlesky 1990).

The semi-arid climate of the southwest occasionally becomes so droughty that seed production is nil. Under these conditions, some ranchers resort to artificial feeding to maintain bobwhite breeding stocks. However, this is not usually recommended as a practice for State and Federal management areas. Doerr (1988) did not find an increase in bobwhite densities or survival where supplemental rations were provided during years of adequate rainfall in southern Texas.

Bobwhite habitat typically comprises more than 1 distinct plant community in the farmlands of the South, Midwest, and Eastern Plains (Fig. 25). Deciduous woodlands provide protective cover, grass-forb communities provide nesting areas and some food, and agricultural crop residues provide winter food. In this land management system, the size of individual units of each community type and the juxtaposition of these units are particularly important. Ideal habitat would include roughly equal amounts of these

Figure 25. Good interspersion of feeding areas, protective cover, and wooded travel lanes characterizes excellent winter cover in agricultural areas

3 communities; each unit should be no larger than 5 to 10 ha (8 to 25 acres), and each cover type should share at least 1 boundary with each of the other two types. This arrangement would provide a high proportion of edges and enable bobwhites to acquire all their needs within a short walk. As the shape of the field becomes more linear, so does the proportion of edge to total area. Consequently, long, narrow fields may contain more area than small, square fields without lowering the quality of habitat.

In harvested crop fields, bobwhites feed almost entirely around the edges near escape cover. Large square fields may contain significant food resources away from these edges, a resource that is rarely used by bobwhites. The use of no-till agriculture, however, increases the availability of food in the interior of these large fields (Dimmick and Minser 1988).

Managing the Harvest

The overriding constraint governing the harvest of bobwhites is preservation of adequate breeding stock to sustain or increase the population.

Bobwhites normally sustain annual mortality rates of 70% to 80%. Hunting mortality is at least partially compensatory for other types of mortality. Consequently, a harvest rate of something less than 70% to 80%, including crippling losses, should be reasonable. Roseberry (1979) suggested that a harvest regime of 40% to 45% is most appropriate. This level of harvest is reasonable and safe, as it accommodates the compensatory nature of hunting mortality and provides a safe margin for inevitable additional mortality. It has been the experience of the author that hunting pressure sufficient to achieve this level of harvest will significantly increase the wariness of bobwhites. Hunters become discouraged from a lack of success and often cease hunting well before the population has been reduced to a level of concern.

<u>Hunting regulations</u>. Hunting regulations for bobwhites are established separately by each State wildlife agency, and there is no Federal oversight. Principal elements of the hunting regulations include season length, season chronology, and daily bag limit; a few states also impose a season limit (Appendix A). Thirty-five states permitted bobwhite hunting during the 1988-89 hunting season. Season length varied from 15 days (Michigan) to 127 days (Rhode Island). Several states offered split seasons or zoned seasons. Twenty-five states opened the bobwhite hunting season in November. The earliest openings were in Idaho on September 17 and in Vermont on September 30. Daily bag limits ranged from 2 birds (Idaho and Ohio) to 15 birds (Texas and 5 hunting zones in South Carolina). Eleven states permitted daily bags of 10 or more; ten of these were located in the southeastern or southwestern United States.

The element of harvest management currently of most concern is the impact of late-season hunting on total mortality and productivity. Fifteen states permit hunting beyond February 15; this practice is common in the South and Southwest. It is generally perceived that the additive impact of hunting mortality increases as winter progresses. Curtis et al. (1989) observed that January through March was a critical mortality period on their study areas in Florida and North Carolina. They concluded that hunting mortality at Fort Bragg, North Carolina, appeared to be additive and contributed to a population decline. However, the contribution was minimal, comprising only 8.9% of annual mortality. Roseberry's (1979) simulated population model indicated that bobwhites experienced increased difficulty in maintaining stable populations as harvesting intensified. His data indicated that a harvest regime of 40% to 45% (including crippling loss) was appropriate. Convincing field

evidence based on experimental research has yet to validate that bobwhite hunting conducted under any existing statewide management system is responsible for regional or statewide declines.

A conservative approach to reduce total mortality would entail reducing season length at the end of the season. This would undoubtedly also reduce recreational opportunity, particularly in the South and Southwest, a trade-off not justified by existing information. Reducing the daily bag limit by as much as 25% would probably have little impact on bobwhite survival, as few hunters achieve near-limit bags. With the opportunity to harvest a legal bag of 10 bobwhites/day, 87,000 Tennessee quail hunters averaged only 3.2 birds/trip in 1986 (Tennessee Wildlife Resources Agency, unpublished 1982-87 Strategic Plan for Bobwhites).

Producing a quality hunt. On privately owned lands or specific Wildlife Management Areas, regulations are often established that are more restrictive than those designed to regulate the statewide harvest. Those regulations often include a limitation on the number of hunter-days per season, a season quota on the total harvest, or a quota on an individual's harvest. On private shooting areas, hunters are occasionally permitted to shoot only on covey rises. The desired objective is to maintain a high-quality hunt for the duration of the season. Intense hunting pressure may or may not lower annual survival rates, but it typically does increase the wariness of bobwhites and progressively lowers hunting success.

Sources of Assistance

There are many sources of assistance to landowners and resource managers who may have problems or questions specific to their particular locale. Several sources that may be helpful are noted below.

State agencies. Individual state wildlife agencies may be subunits of larger resource management bureaus, such as the Wisconsin Department of Natural Resources, or may stand independent, e.g., Tennessee Wildlife Resources Agency. Most of these agencies have an upland game bird specialist in the Division of Wildlife Management. This individual can provide information about habitat management and sources of plant materials.

SCS. The Soil Conservation Service (SCS) of the US Department of Agriculture maintains field offices in most counties, as well as wildlife specialists in the state capitol. SCS biologists can provide technical assistance in

in the field; they can also provide information about cost sharing for wildlife conservation practices.

State universities. Land-grant institutions frequently staff Extension Wildlife Specialists who can provide literature and technical information directly to landowners or through County Extension Agents. County Extension Offices are good sources of information on planting techniques and suitable varieties for establishment.

Quail Unlimited (QU). QU is a private conservation organization that supports good habitat management for all species of quail in North America. QU is headquartered at the address below; there are also several state and regional offices.

Quail Unlimited, Inc.
Box 10041
Augusta GA 30903

Research facilities. Some independent research groups devote part of their research efforts to bobwhites and/or other quail species. Some that provide technical information are listed below.

Ames Plantation
The University of Tennessee Agricultural Experiment Station
Box 389
Grand Junction, TN 38039-0389
(Special emphasis: Bobwhite management in the Mid-South; pointing dog field trial management)

Caesar Kleberg Wildlife Research Institute
Texas A&M University
College Station, TX 77843
(Special emphasis: Bobwhite management in southwestern rangelands)

Cooperative Wildlife Research Laboratory
Southern Illinois University
Carbondale, IL 62903
(Special emphasis: Bobwhite ecology and management in the Midwest)

Southeastern Cooperative Wildlife Disease Study
College of Veterinary Medicine
The University of Georgia
Athens, GA 30602
(Special emphasis: Diseases and parasites)

Tall Timbers Research Station
Route 1, Box 678
Tallahassee, FL 32312
(Special emphasis: Bobwhite management in the southeastern Coastal Plain; prescribed fire as a management technique)

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APPENDIX A

BOBWHITE QUAIL HUNTING REGULATIONS DURING 1988-1989

State	Bag Limit Daily	Bag Limit Possession	Bag Limit Season	Open Season Date Start	Open Season Date End	Open Season Total Days
Alabama	12	12	--	11-19	02-28	102
Arkansas						
North	8	16	--	11-19	12-13	87
South	8	16	--	11-19	01-28	102
Colorado						
NE	8	16	--	10-22	12-14	44
NW & S	8	16	--	11-19	02-02	76
Delaware	8	--	--	11-21	01-11	98
				01-16	02-28	
Florida	12	24	--	11-12	03-05	114
Georgia						
South	12	--	--	11-20	02-28	101
Idaho	2	2	--	09-17	12-31	106
Illinois						
North	8	16	--	11-05	01-02	59
South	8	16	--	11-11	01-09	60
Indiana						
North	5	10	--	11-04	12-18	44
South	8	16	--	11-04	01-15	72
Iowa	8	16	--	10-29	01-31	95
Kansas						
West	8	24	--	11-19	01-31	74
East	8	24	--	11-12	01-31	81
Kentucky	8	16	--	11-22	02-19	90
Louisiana	10	20	--	11-24	02-28	97
Maryland						
NW	6	12	--	11-15	01-14	61
Other	6	12	--	11-15	02-28	106
Massachusetts	5	10	25	10-20	11-25	37
Michigan	5	10	15	10-28	11-11	15

(Continued)

State	Bag Limit Daily	Bag Limit Possession	Bag Limit Season	Open Season Date Start	Open Season Date End	Open Season Total Days
Mississippi	12	24	--	11-24	02-28	97
Missouri	8	16	--	11-01	01-15	76
N. Carolina	10	20	--	11-19	02-28	102
New Hampshire	5	--	25	10-01	12-01	62
Nebraska						
West	6	18	--	11-05	01-31	88
East	8	24	--	11-05	01-31	88
New Jersey	7	--	--	11-12	02-20	101
New York	6	--	40	11-01	12-31	61
Ohio	2	6	--	11-04	01-02	60
Oklahoma						
East	10	20	--	11-24	02-15	84
West	10	20	--	11-20	02-01	74
Rhode Island	5	--	--	10-15 12-12	12-02 02-28	127
S. Carolina 98-101	10,12,15*				11-21	03-04
S. Dakota						
Unit 3	5	15	--	11-01	12-10	40
Tennessee	10	20	--	11-12	02-28	109
Texas	15	45	--	10-29	02-26	121
Vermont	4	8	--	09-30	11-09	41
Virginia	8	--	--	11-21	01-31	72
West Virginia	7	21	--	11-04	02-28	117
Washington						
Western	5	15	--	10-15	11-30	47
Eastern	10	30	--	10-15	01-08	86
Wisconsin	5	10	--	10-15	12-07	54

* South Carolina has 11 zones with separate regulations, including bag limit, opening day, and season length.

APPENDIX B

SCIENTIFIC NAMES OF MAJOR BOBWHITE FOODS LISTED IN TABLE 3
(Listed Alphabetically by Common Name)

American beautyberry (*Callicarpa americana*)
Ash (*Fraxinus* spp.)
Beggarticks (*Bidens* spp.)
Beggarweeds (*Desmodium* spp.)
Black locust (*Robinia pseudoacacia*)
Blackberries (*Rubus* spp.)
Bluestem pricklypoppy (*Argemone intermedia*)
Bristlegrass (*Setaria* spp.)
Browntop millet (*Panicum fasciculatum*)
Bull grass (*Paspalum boscianum*)
Bush clovers (*Lespedeza* spp.)
Common persimmon (*Diospyrus virginiana*)
Common ticklegrass (*Agrostis hyemalis*)
Copperleaf (*Acalypha* spp.)
Corn (*Zea mays*)
Cowpeas (*Vigna* spp.)
Crab grass (*Digitaria* spp.)
Cranesbill (*Geranium* spp.)
Dogwoods (*Cornus* spp.)
Dollar-weed (*Rhynchosia americana*)
Doveweed (*Croton* spp.)
Erect dayflower (*Commelina erecta*)
Fall white aster (*Aster pilosus*)
Foxtail grasses (*Alopecurus* spp.)
Fragrant sumac (*Rhus aromatica*)
Fringed signalgrass (*Brachiaria ciliatissima*)
Fringeleaf paspalum (*Paspalum ciliatifolium*)
Goldenrod (*Solidago* spp.)
Grapes (*Vitis* spp.)
Ground cherry (*Physalis viscosa*)
Ground nut (*Apios americana*)
Hackberry (*Celtis laevigata*)
Hoary milkpea (*Galactia canescens*)
Hog peanut (*Amphicarpa bracteata*)
Honeysuckles (*Lonicera* spp.)
Illinois bundleflower (*Desmanthus illinoensis*)
Jewel-weeds (*Impatiens* spp.)
Johnsongrass (*Sorghum halepense*)
Lespedezas (*Lespedeza* spp.)
   Bicolor lespedeza (*L. bicolor*)
   Common lespedeza (*L. striata*)
   Daurica lespedeza (*L. daurica*)
   Korean lespedeza (*L. stipulacea*)
   Sericea lespedeza (*L. cuneata*)
   Wooly lespedeza (*L. tomentosa*)
Mesquite (*Prosopis glandulosa*)
Milk peas (*Galactia* spp.)

(Continued)

Netleaf hackberry (*Celtis reticulata*)
Nightshades (*Solanum* spp.)
Nutrushes (*Scleria* spp.)
Oaks (*Quercus* spp.)
   Live oak (*Q. virginiana*)
   Shin oak (*Q. havardi*)
Panic grasses (*Panicum* spp.)
Partridge pea (*Cassia* spp., primarily *C. fasciculata*)
Paspalums (*Paspalum* spp.)
Pines (*Pinus* spp.)
Poor Joe/rough buttonweed (*Diodia teres*)
Pricklyash (*Zanthoxylum clava-herculis*)
Rag sumpweed (*Iva xanthifolia*)
Ragweeds (*Ambrosia* spp.)
   Common ragweed (*A. artemisiifolia*)
   Giant ragweed (*A. trifida*)
   Western ragweed (*A. psilostachya*)
Redroot amaranthus (*Amaranthus retroflexus*)
Rough sumpweed (*Iva ciliata*)
Roundseed dicanthelium (*Panicum sphaerocarpon*)
Rushes (*Juncus* spp.)
Russian olive (*Elaeagnus angustifolia*)
Sandlilly (*Mentzelia* spp.)
Sassafras (*Sassafras albidum*)
Sesbania (*Sesbania macrocarpa*)
Slender evolvulus (*Evolvulus alsenoides*)
Small wildbean (*Strophostyles pauciflorus*)
Smartweeds (*Persicarea/Polygonum* spp.)
Snakeweed (*Gutierrezia sarothrae*)
Snow-on-the mountain/prairie (*Euphorbia marginata*)
Sorghum (*Sorghum vulgare*)
Soybean (*Glycine max*)
Spiny hackberry (*Celtis pallida*)
Spreading panicum (*Panicum diffusum*)
Spurred butterfly pea (*Centrosema virginianum*)
Sumacs (*Rhus* spp.)
Sunflowers (*Helianthus* spp., primarily *H. annuus*)
Sweet clover (*Melilotus* spp.)
Sweetgum (*Liquidambar styraciflua*)
Switchgrass (*Panicum virgatum*)
Texas millet (*Panicum texanum*)
Verbena (*Verbena* spp.)
Vetches (*Vicia* spp.)
Wheat (*Triticum aestivum*)
Wild beans (*Strophostyles* spp.)
Wild rice (*Zizania texana*)
Witchgrass (*Panicum capillarae*)
Woodsorrels (*Oxalis* spp.)
   Yellow woodsorrel (*O. dillenii*)
Wooly bumelia (*Bumelia celastrina*)
Woolybucket bumelia (*Bumelia lanuginosa*)
Yellow foxtail (*Setaria glauca*)